

APPLICATION OF REMOTE SENSING IN SOUTH DAKOTA  
TO PROVIDE ACCURATE INVENTORIES OF AGRICULTURAL  
CROPS, ENHANCE CONTRAST IN PHOTOGRAPHIC PRODUCTS,  
MONITOR RANGELAND HABITAT LOSS, MAP ASPEN,  
AND PREPARE HYDROGEOLOGIC SURVEYS

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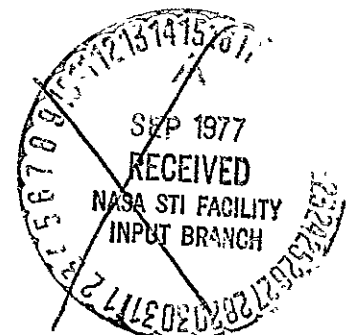
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ORIGINAL CONTAINS  
COLOR ILLUSTRATIONS





REMOTE SENSING INSTITUTE

SOUTH DAKOTA STATE UNIVERSITY

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September 7, 1977

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Gentlemen:

Please find enclosed two (2) copies of the FY 1977 annual  
report on our NASA grant NGL 42-003-007.

Sincerely yours,

Victor I. Myers  
Director

VIM/dr

Enclosures

cc: Joe Vitale

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## ABSTRACT

The use of remote sensing technology has been evaluated and/or incorporated in the melioration of various public agency decision-making processes in South Dakota. Efficacious useage of each application will be abstracted in the ensuing paragraphs.

Recent research has indicated that soils influence spectral signatures of row crops on Landsat CCT's. The contribution of soil reflectance to Landsat spectral signatures has been analyzed on a county wide basis. Seven major soil associations (five associations contained the majority of cropped lands) are located in Codington County, South Dakota. Training data were collected in each of the five cropped associations. Digital analysis of Landsat CCT's indicated that two discrete spectral background reflection zones occurred among the five soil zones. K-CLASS classification of corn revealed that accuracy increased from 42 percent to 83 percent when two background zones were used, compared to classification of corn stratified by five soil zones.

A photographic technique for contrast enhancement of Landsat imagery was documented and illustrated. An increase in photographic contrast (gamma) results in greater density differences between scene features and a better radiometric resolution providing the maximum interpretative potential of Landsat imagery. The process involves selectively varying film type developer and development time to produce higher contrast in the reprocessed image. The technique has applications in any project which utilizes Landsat imagery.

Land conversion in western South Dakota has been qualitatively noted in recent years by Game, Fish, and Parks personnel. The impact of this loss on wildlife cannot be fully assessed unless a quantitative appraisal of the habitat loss is ascertained. Interpretation of rangeland and cropped land were made on 1968 black and white aerial photography and 1976 Landsat imagery. Losses or rangeland habitat were determined; soil interpretative data (land capability and habitat ratings) was used to evaluate the quality of habitat loss. The loss of good rangeland habitat was 33,000 ha, fair-24,000 ha, and poor-7,000 ha between 1968 and 1976.

Thermal imagery and/or aerial photography was obtained for selected areas in South Dakota to document what interpretations would be beneficial to hydrogeologic mapping. Thermal imagery was found to be particularly useful for locating potential sources of sub-surface water and geo-thermal energy, estimating evapotranspiration, and inventorying irrigated land. Since water features are dominant on thermal imagery, the thermal data can provide ancillary information in hydrogeologic investigations.

Recent applications of surveys and programs developed under NASA funding are summarized.

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Mr. James Hyland, Geologist of the Soil Conservation Service, provided valuable assistance in the joint hydrogeologic evaluation and preparation of the manuscript.

APPLICATION OF REMOTE SENSING TECHNOLOGY IN SOUTH DAKOTA TO  
PROVIDE ACCURATE INVENTORIES OF AGRICULTURAL CROPS,  
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The major objective of the NASA project is to provide remote sensing techniques that can be incorporated into programs of public service. Remote sensing technology can often provide valuable data to assist public agencies in their decision and management processes. The programs where these applications are currently being made are: 1) the application of remote sensing technology (using Landsat) to account for variable background reflectance in the establishment of a more accurate inventory of agricultural crops in eastern South Dakota; 2) the use of photographic methods to enhance contrast in Landsat imagery; 3) the use of historical aerial photography and current Landsat coverage of western South Dakota to determine recent rangeland habitat losses; 4) the evaluation of Landsat and other data sources to map and eventually monitor aspen stands in the Black Hills; and 5) the use of thermal imagery in hydrogeologic surveys. Because of the diverse nature of these studies, they will each be addressed in sequence as separate sections.

#### AGRICULTURAL INVENTORY

Numerous efforts have been undertaken to classify various agricultural crops from Landsat multispectral scanner (MSS) reflectance values. These efforts have been directed toward the development and/or improvement of crop inventories. Many of these studies have acknowledged that background reflectances of soil cause variable crop signatures thus reducing overall classification accuracy (Heilman, 1974 and Lemme, 1975).

Reflectance as recorded from a vegetated surface (viz. row crop) is a composite of plants, soils, and shadows. Richardson et al. (1977) developed models from Landsat data which had variable success in eliminating background contribution to vegetative signatures. Their study incorporated various crop parameters (e.g. leaf area index, percent cover), gathered from a necessarily limited number of fields, with the Landsat data. Elimination of confounding background reflectance is especially important in row crops which may have a considerable amount of soil contribution to reflective signatures. The fact that soil associations maps have been successfully interpreted from Landsat imagery (Frazee et al., 1974) evidences the background variability that can be interposed in crop inventories.

Wiegand et al. (1977) found three significant regions of soil reflectance (low, medium, and high) when using Landsat MSS data in a vegetative modeling study. Their study used a limited number of fields from which the intensive ground data was collected. They used stratified soil reflectance as base references for vegetation monitoring. They noted the need to "tune" such studies according to the particular crops and soils of a physiographic region.

Objectives of this study are to improve crop inventory procedures through the stratification of Landsat MSS data into reflectance zones. A regional approach will be taken to account for variable soil or background reflectance. Soil association data and contrast-enhancement photographic procedures will be tested as a means of deriving background reflectance zones. Also, the development of a rationale for extending strata in this

## PROCEDURES

The procedure and results are divided into phase one (completed), the results of which were detailed in the FY 1978 NASA proposal, and phase two (up-to-date activities).

### Phase One

Phase one tested concepts and established the foundation for the expansive efforts of phase two. Therefore, only a cursory description of phase one will be included.

Field data was collected in Codington County (figure 1) during the 1976 growing season. RB-57 imagery (1:63,360) was used in the field to record crop locations. Collection of corn data were emphasized; however, other cropped and noncropped areas were also recorded.

A July 1976 Landsat CCT (computer compatible tape) covering Codington was obtained to facilitate the digital analyses of the field data. Field sites were located and labeled on CCT printer maps. The digital data were then extracted, error-checked, and statistically analyzed. Analysis of variance, Duncan's multiple range test, and K-Class procedures were used to compare digital signatures and determine and test the reflectance zones on the four Landsat bands and by the seven soil associations.

Contrast enhancement techniques were used on a May 1976 Landsat image; the image was then photointerpreted to derive background reflectance zones. Since this process has important implications it was felt a separate discussion was warranted (see page 13 for a more

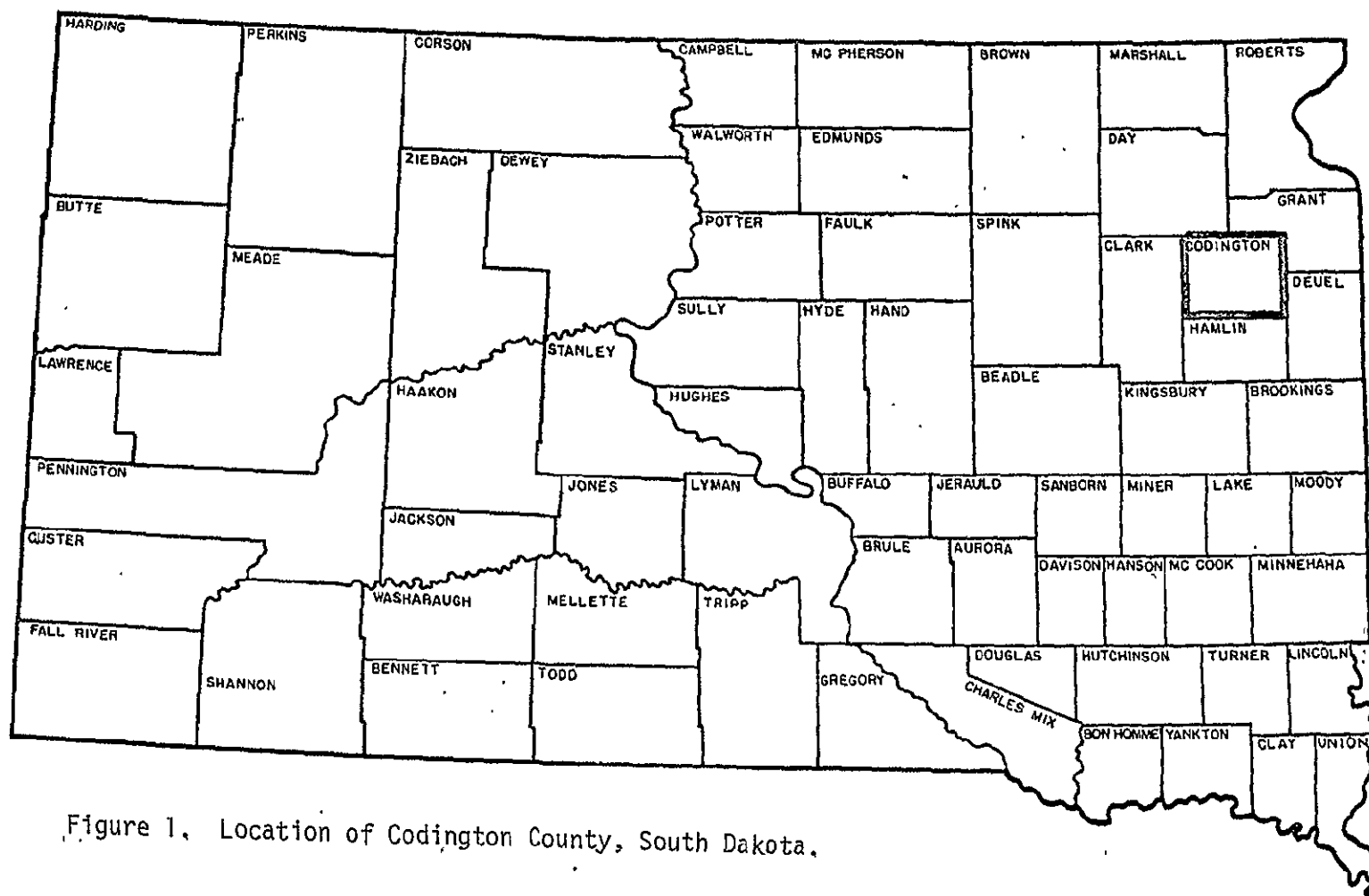


Figure 1. Location of Codington County, South Dakota.



complete description). Several critical factors are involved when attempting to delineate zones of contrasting background reflection on Landsat imagery; they are: 1) imagery date, 2) soil moisture status and its immediate history, 3) presence of cropped soil inclusions in otherwise noncropped soil associations, and 4) the masking effect of tame grasses (alfalfa, etc.) grown across soils of differing reflectance. This type of product will be further tested in phase two of this project.

#### Phase Two

The ground work is completed for the Landsat scene which covers southeastern South Dakota (figure 2). The data collection again emphasized locating corn fields with other crops also being recorded. The field data were collected and analyzed within soil association. Available county soil surveys will be used, when necessary, in the determination of composition within soil association units.

The same extraction and statistical analyses referred to in phase one will be used in phase two. Alternative methods will be investigated to speed the digital extraction procedure and to increase confidence in boundary descriptions. A June 1977 Landsat CCT has been ordered.

Several assumptions have been made concerning the field data; they are: 1) stage of corn phenology is approximately the same across the sample area, 2) the same soil association will possess a similar reflectance everywhere on the Landsat scene, and 3) row crop weediness (or lack of weeds) is approximately the same across the

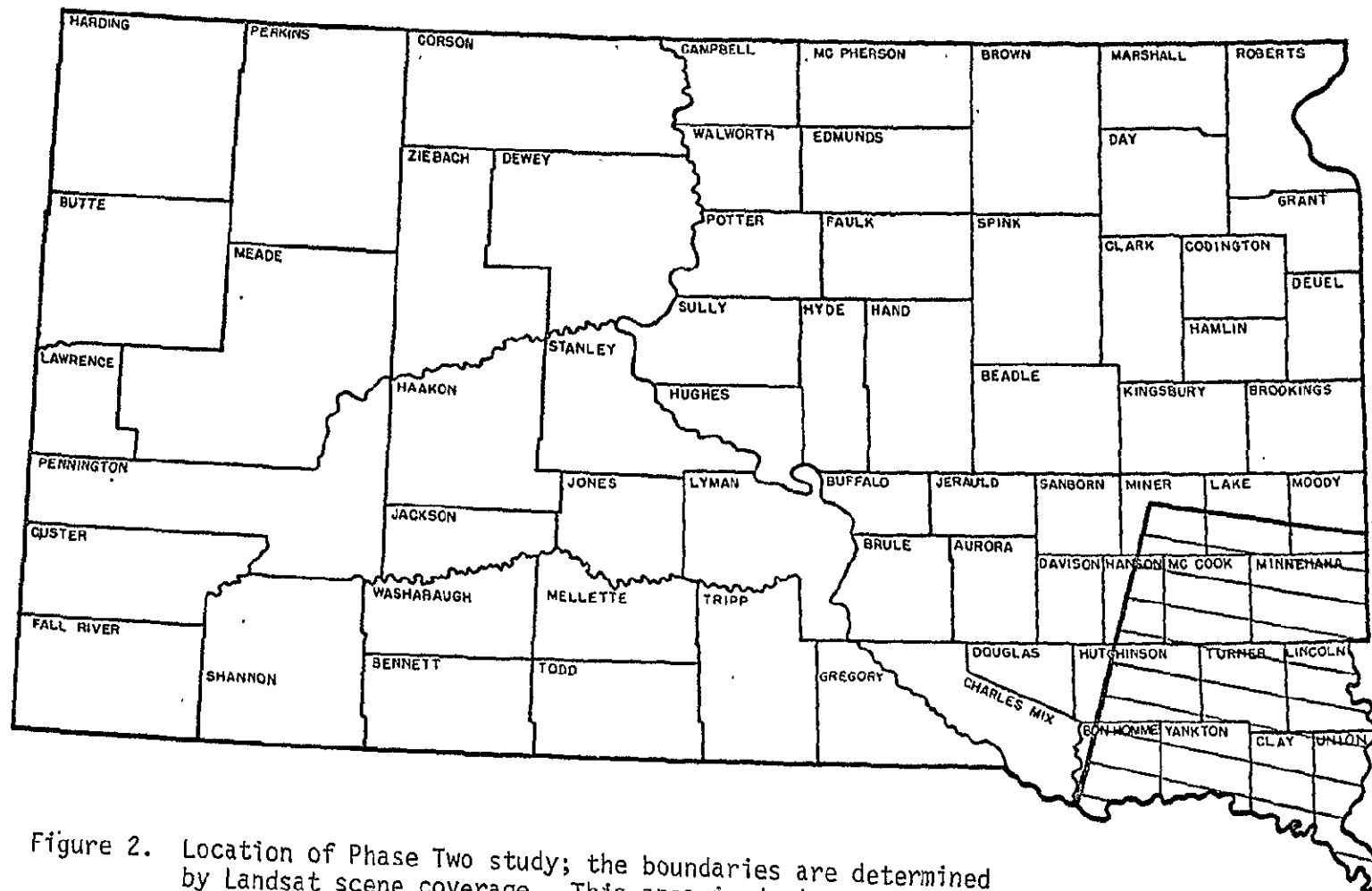


Figure 2. Location of Phase Two study; the boundaries are determined by Landsat scene coverage. This area is dominated by Udic Ustoll soils.

scene. Although the aforementioned factors may cause some variance, these factors will not be significant contributors to the formulation of the background zones on Landsat data.

## RESULTS AND DISCUSSION

Initial results of the Codington County project have been outlined in FY 1978 NASA proposal. The results presented will be a continuance of the previously recorded results.

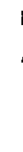
Codington County is located in a region of diverse soils (figure 3). Each soil association unit contains minor soils and inclusions which are not listed in the legend. It is thereby possible for a crop to be growing in a minor soil which is a major soil of another association. This may apply to minor cropped soils located in otherwise nontillable associations; ideally such associations would be grouped into the appropriate reflectance strata.

The final reflectance zones of Codington County are detailed in figure 4. Two of three reflectance zones were determined predominantly by statistical analysis; the third zone contained too few cropped areas (the cropped areas were mostly soil inclusion) to be statistically tested. This points out that the land use differences (as noted on Landsat imagery) do not necessarily provide a basis for background reflectance differentiation. The cropped portion of soil association four (northwest corner of figure 4) was included in reflectance zone one because of factors mentioned in the previous paragraph.

U. S. DEPARTMENT OF AGRICULTURE  
SOIL CONSERVATION SERVICE  
SOUTH DAKOTA AGRICULTURAL EXPERIMENT STATION  
**GENERAL SOIL MAP**  
CODINGTON COUNTY, SOUTH DAKOTA

Scale 1:199,060

1 0 1 2 3 4 Miles



**SOIL ASSOCIATIONS**

- 1 Poinsett-Waubay Oldham association: Nearly level or gently undulating, medium-textured and moderately fine textured soils formed in silty and loamy glacial drift
- 2 Poinsett Buse-Parnell association: Undulating or steep, medium-textured and moderately fine textured soils formed in silty and loamy glacial drift
- 3 Brookings Kranzburg Vienna association: Nearly level to sloping, medium textured and moderately fine textured soils formed in loess and loamy glacial till
- 4 Forman Buse-Parnell association: Gently undulating to rolling, medium textured and moderately fine textured soils formed in clay loam glacial till
- 5 Buse Sioux association: Rolling or steep, medium-textured and moderately coarse textured soils formed in glacial drift
- 6 Establine Fordville-Renshaw association: Nearly level or gently sloping, medium textured and moderately coarse textured soils underlain by sand and gravel on stream terraces and outwash plains
- 7 Lamoure Paville association: Nearly level, moderately fine textured soils on flood plains

October 1965

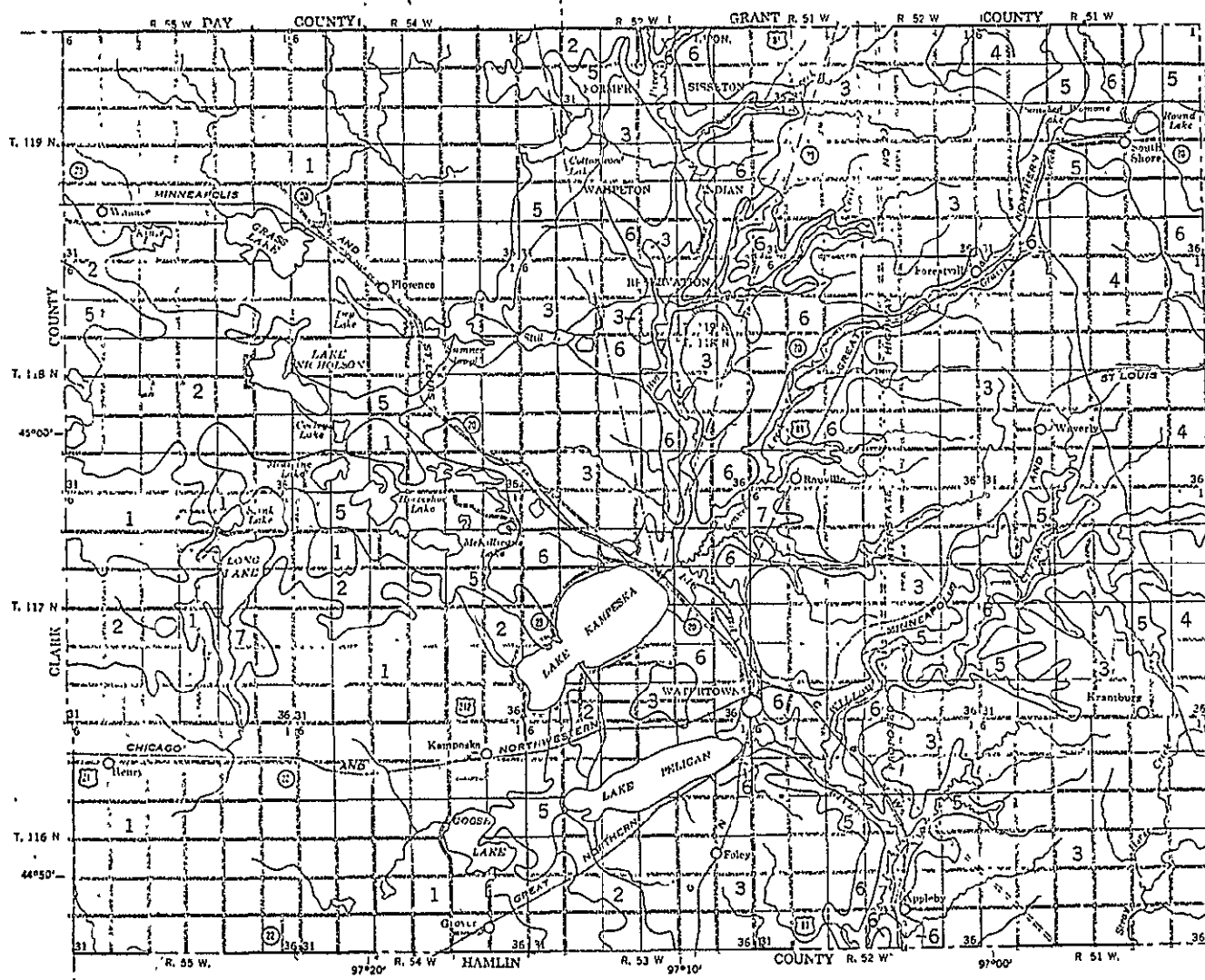


Figure 3. Codington County general soil map.

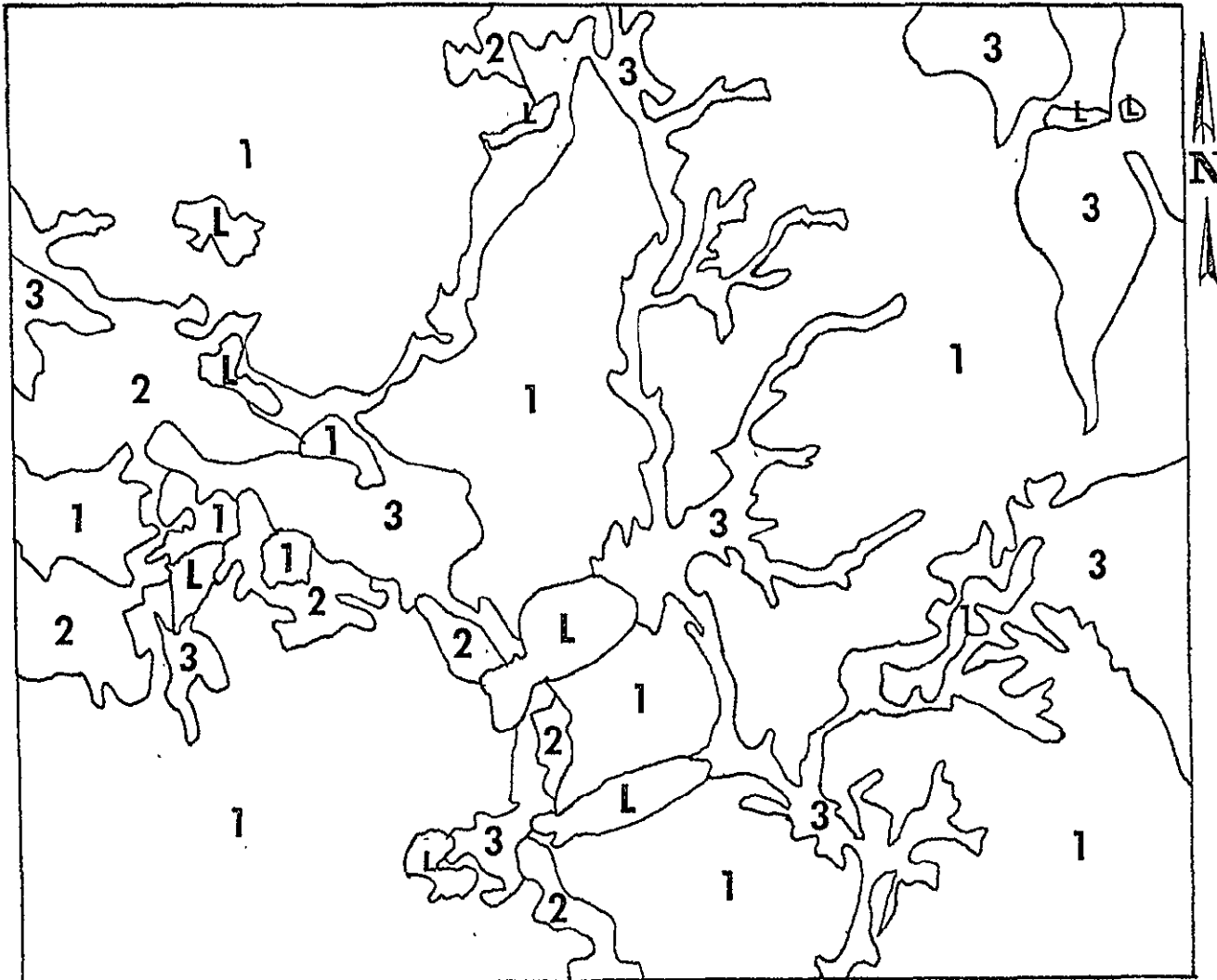


Figure 4. Three reflectance zones of Codrington County. Reflectance zone 1 includes soil association one, three, and six (see figure 3 for soil legend); zone 2 is soil association 2, and zone 3 is soil associations five and seven. Lakes are represented by L.

Once the two zones were established, they were tested on the K-Class program. Corn training data (from Landsat CCT's) from each of five soil strata was classified. The results improved from 42% to 83% classification accuracy when two significant strata were used instead of the five strata. However, this increase in accuracy would be somewhat expected because the probability of misclassification decreases with a decrease of somewhat homogenous groups. If each of the soils possessed a different reflectance value, the five strata would then have been best. However, the implication of this increased classification accuracy is an important consideration in larger areal classifications. Minimal stratifications across a reporting district could cause fewer data handling problems as well as increasing classification accuracy.

The effect of 1976 drought on the derived zones is unknown. Drought effects on crop vigor and soil reflectance are major considerations. The 1977 growing season has been near ideal thus far in most of eastern South Dakota. The advanced growth stages of agricultural crops (two to three weeks) has necessitated the ordering of an early June CCT. Numerous corn fields have been recorded for each major soil association in southeastern South Dakota. Ancillary crops have also been recorded but the results of the phase one study indicate that background reflectance contributes little or nothing to reflectance signatures obtained from July Landsat data. Thus, corn will be the major crop tested in the zonal development.

The development of background reflectance strata can help increase accuracy of crop classification using Landsat CCT. An

increased crop classification can be used with other data to determine crop production. Crop Reporting Districts, Statistical Reporting Service, State Agriculture Departments are among the agencies which would have use for increased crop classification accuracy. Foreign marketing strategies, livestock feed purchases, grain storage and handling facilities are among the concerns which could show direct benefit from the increased accuracy of crop classification and any ensuing production estimates. Crop production estimates rely heavily on accurate acreage of crops; other factors such as climate and soil productivity are also important.

## REFERENCES

- Heilman, J.L. 1974. The application of ERTS-1 multispectral imagery for crop resource evaluation and inventory. M.S. Thesis, South Dakota State University, Brookings.
- Lemme, G.D. 1975. The influence of soils and vegetation on Landsat spectral signatures. M.S. Thesis, South Dakota State University, Brookings.
- Frazee, C.J., P.H. Rahn, F.C. Westin, and V.I. Myers. 1974. Use of ERTS-1 imagery for land evaluation in Pennington County, South Dakota. P. 549-568. Proc. ninth intl. symp. on remote sens. of envir. Ann Arbor, Michigan.
- Richardson, A.J., C.L. Wiegand, H.W. Gausman, J.A. Cuellar, and A.H. Gerberman. 1975. Plant, soil, and shadow reflectance components of row crops. Photogram. Eng. and Remote Sens. Vol. 41 (11): 1401-1407.
- Wiegand, C.L., H.W. Gausman, R.W. Leamer, A.J. Richardson, J.H. Everitt, and A.H. Gerbermann. 1977. Soil, water, and vegetation conditions in South Texas. Type III Final Report for Goddard Space Flight Center, Greenbelt, Md.



### INTRODUCTION

For many applications standard Landsat film products lack the tonal contrast required to easily distinguish scene features. Sixty-four brightness levels in each of the four MSS bands are recorded at the satellite. This signal is calibrated and expanded to 128 prior to generating standard film products. When imagery is exposed the brightness levels must be recorded within the density range of the photographic emulsions used. The radiometric range or exposure latitude of most films is approximately two standard density units. In numerous scenes, primarily in MSS 4, there is a relatively uniform scene reflectance and the total density range of the film is not utilized. In standard products, if data do not use the density range of 2.0, exposures are adjusted so that saturation occurs at the second darkest step on the standard transmission gray wedge printed on each film product.

During exposure of the original imagery a film gamma corrector is used to reduce the slope of the  $D\text{-log } E$  curve to  $\delta = 1$  and to straighten the toe and shoulder in an attempt to produce a linear relationship between film transmission and MSS digital count. However, if the minimum film transmission ( $T_{\text{Min}}$ ) is not equal to zero, the  $D\text{-log voltage}$  curve deviates from  $\delta = 1$  at high densities resulting in lower contrast in the darker portions of the image. Succeeding generations available to the user are reproduced at  $\delta = 1$  on the linear portion of the curve of film used.

It was demonstrated in this project that the degree of image contrast could be adjusted in a modestly equipped photo laboratory using relatively simple photographic principles. Contrast in a reprocessed image can be increased by selectively varying film type, exposure, developer chemistry, and the duration of development. The primary objective of this report is to document and illustrate the technique that was developed.

#### Photographic Contrast Enhancement Theory

Film "contrast" or "gamma" is the slope of the straight line portion of the characteristic curve ( $D-\log E$ ) and is usually measured at the tangent formed by a projection of the straight line portion of the curve and the  $\log E$  axis. The curve describes the photographic characteristics of the film for a given developer and development time. Different gammas can be obtained by using different film and developer combinations and by varying development times. In general, gamma increases for a specific film-developer combination with increased development time if developer temperature remains constant.

The effect of increasing contrast can best be explained graphically. Figure 5 illustrates the characteristic curves for a contrast enhanced reprocessed image as compared to the characteristic curve of the standard product.

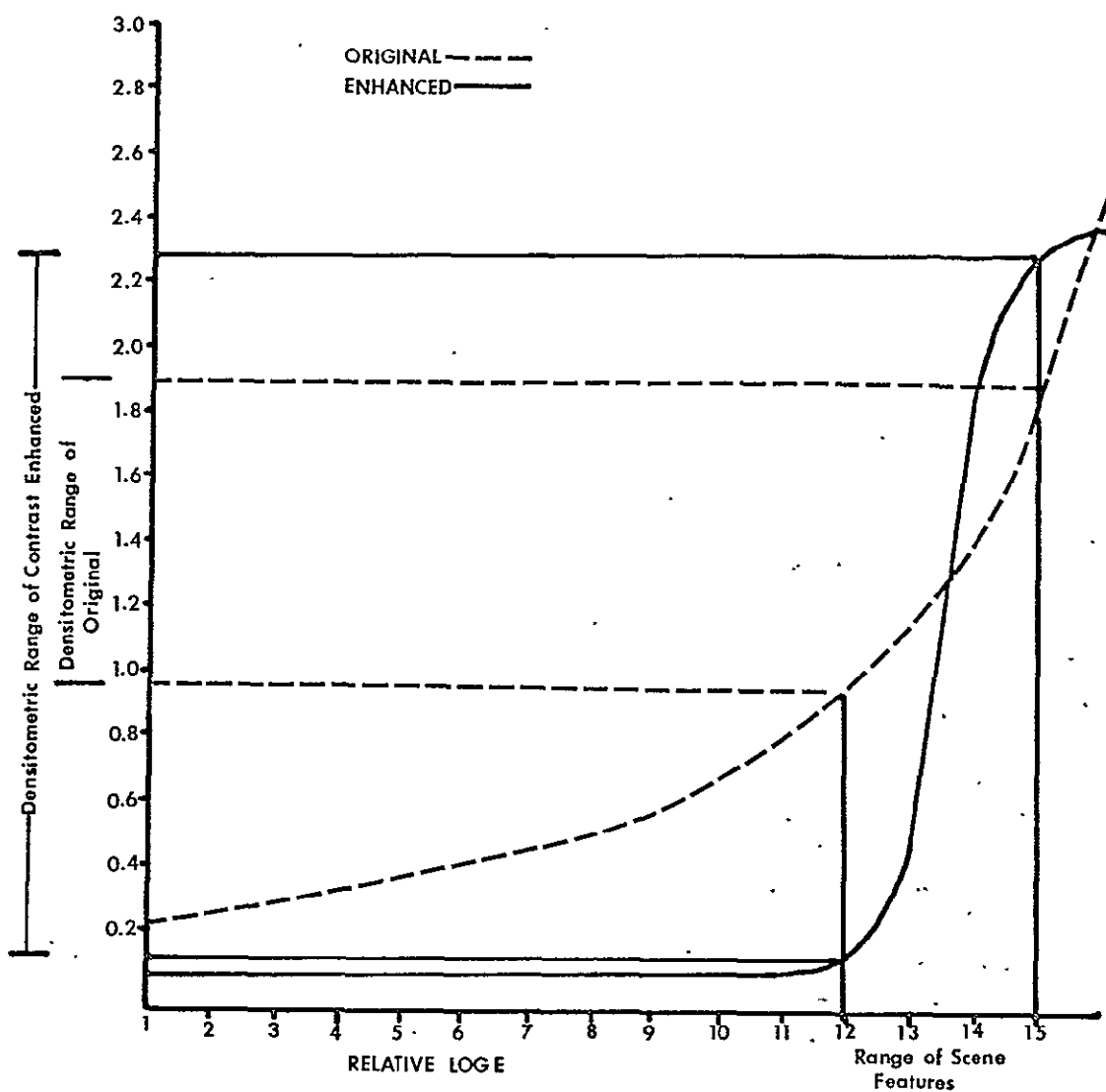


Fig. 5. Graphic illustration comparing the characteristic curves of standard product and contrast enhanced reprocessed image. Data plotted for MSS 4 image #2337-07292.

The gamma of the standard product original is approximately equal to one. As in many MSS 4 images, the scene features utilize only a short range of the potential recording capability of the film and cover only a short density range. The reprocessed image has a gamma greater than four and "stretches" the informational content over a much larger density range. This results in greater density differences between scene features providing a more interpretable image. It is also apparent on the graph that for a given densitometric resolution the best radiometric resolution occurs with the higher contrast. The technique is applicable to all bands, however, the stretch generally required for MSS 5 and 7 is in the range of  $\delta = 1.5$  to 3.0. It is possible to increase contrast to a greater degree for only selected scene features with a subsequent loss of the additional information in the data that does not fall within the grey-level region to be stretched. The effect of this contrast enhancement is similar to the computerized "contrast stretch" of digital Landsat computer compatible tapes (CCT's).

### Materials and Methods

The procedure developed in this project involved selecting various film types, developers, and development times to produce a range of gammas in the reprocessed image from below one to greater than four. Sensitometry was exposed on the films and development time was varied for each developer. The characteristic curves were

plotted for each combination and gamma was measured. Table 1 is a list of film and developer combinations and the resulting gamma range for each.

Table 1.

Film	Developer	Gamma Range
Professional Copy 4125	D-76	<1 - 1.90
Professional Copy 4125	D-19	1.80 - 2.7
Kodalith Ortho Types 3 6556	Kodalith	>4

For a given film-developer combination, increased development time increased gamma.

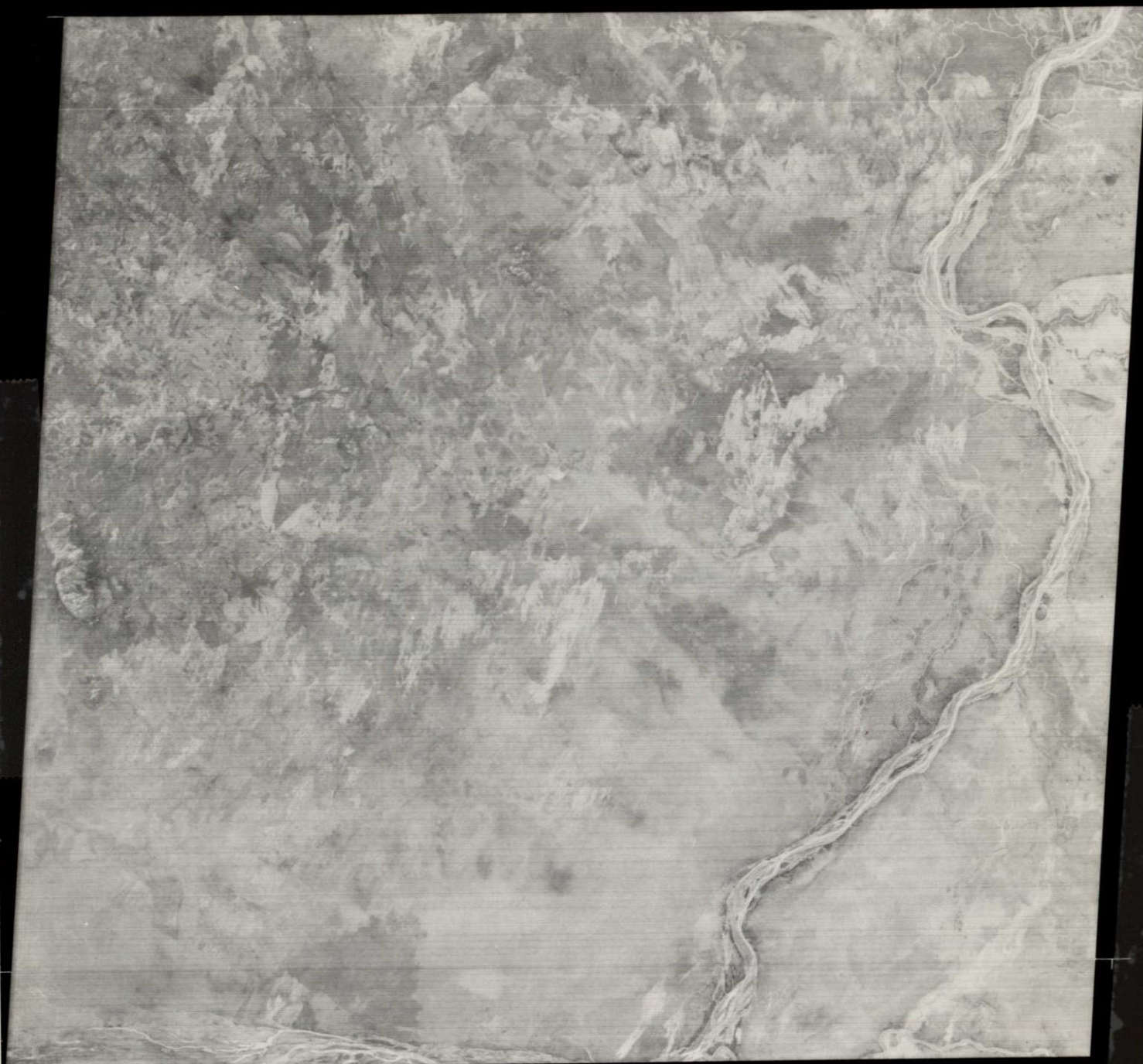
Prior to reprocessing, an image was analyzed on Spatial Data (Data color 703), an electronic density slicer, to determine the range of scene features relative to the annotation gray scale printed on each scene. The image was contact printed onto the selected film and developed for the specific time required to produce the correct degree of contrast enhancement without loss of information content. Exposure was controlled so that data will remain in the straight line portion of the characteristic curve in order to maintain the linear relationship between film density and digital count.

## Results

The effect of contrast enhancement is evident on the reprocessed imagery when it is compared to the standard product (Fig. 6a + 6b). Figures 6a and 6b are contact prints of positive MSS standard and reprocessed imagery. The density range of the scene features in the standard product is .94 density units (.95-1.89) as compared to 2.19 density units (.08-2.27) in the "stretched" image. A graphic illustration can be seen in Figure 1. In general, less stretch is required in bands MSS 5 and 7 and the effect is not as evident on imagery. Color composites of reprocessed imagery exhibit a wider range of colors and hues than do standard color composites.

## Conclusions

The use of photographically contrast enhanced imagery has applications in any project which utilizes Landsat imagery. This particular technique was developed for use with Landsat imagery, however, with slight modifications it would be applicable for use with other types of photographic data. The products, either black and white or color composites, provide the user with the maximum interpretation potential. The results are similar to those produced in a computerized contrast stretch of digital CCT data, but the photographic enhancement can be prepared at a fraction of the cost. The contrast enhanced imagery can be



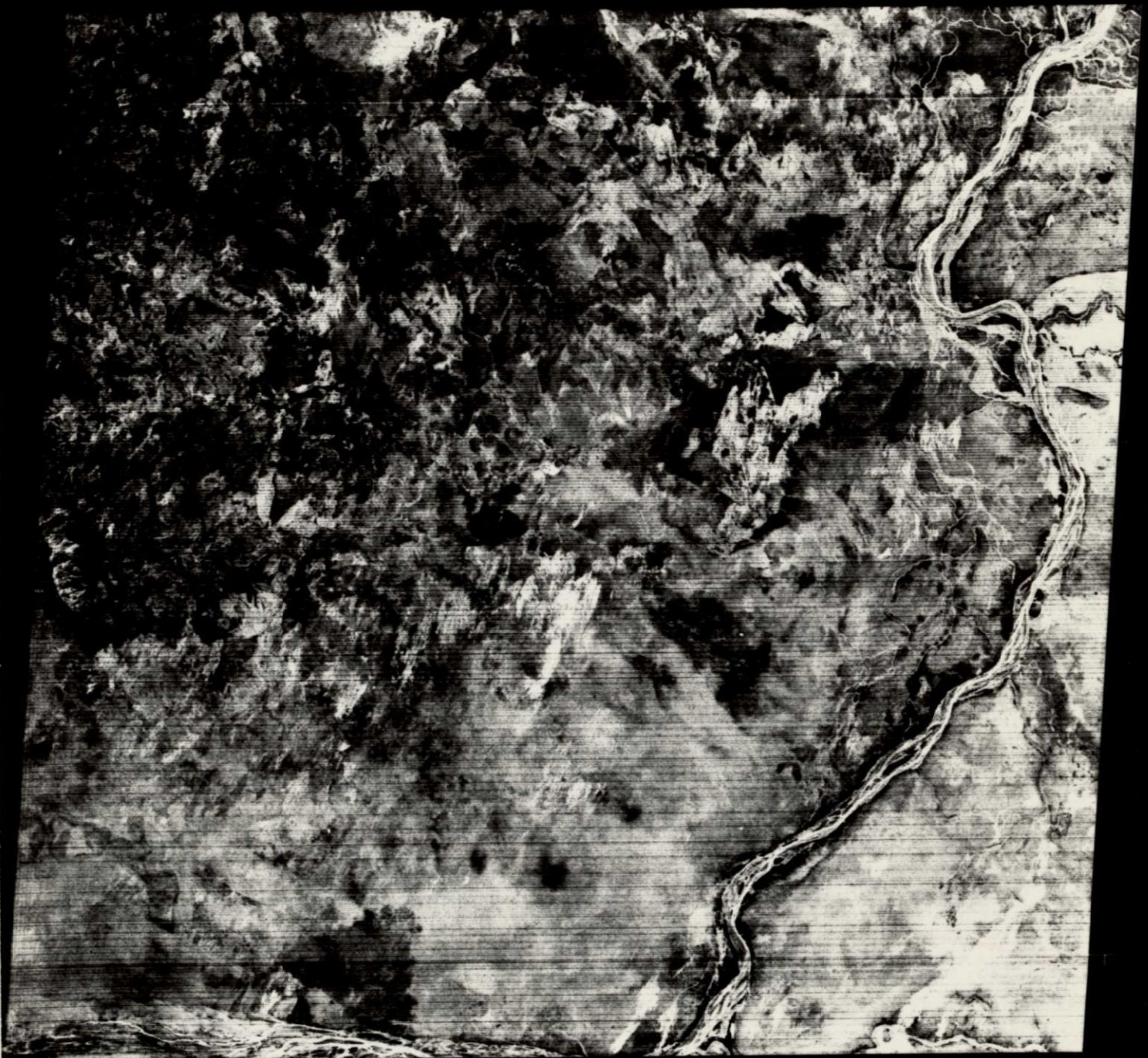
E031-001  
25DEC75 C N10-11/E031-31 N N10-10/E031-33 MSS 4  
E031-301  
R SUN EL41 AZ134 189-4693-A-1-N-D-2L NASA ERTS E-2337-07292-4 01  
E032-001  
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E031-301  
N009-301  
E032-001

Fig. 6a. A negative print of a scene in Sudan which reflects the tonal contrasts apparent in the original standard transparencies.



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E031-001  
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N009-301 E032-001  
0-2

Fig. 6b. Photographically contrast enhanced MSS 4 image  
of the same region in Sudan as in Figure 6a.



produced in a modestly equipped photo laboratory. The technique has many applications in developing countries which do not have the resources or technical expertise to purchase or man an extensive computer system. Gamma manipulation can be used to adjust reflectance differences in adjacent scenes in order to produce black and white or color tone-matched imagery for photo mosaics.

USE OF REMOTE SENSING TECHNOLOGY TO  
MONITOR AND EVALUATE THE IMPACT OF CULTIVATION  
ON RANGELAND ECOSYSTEMS IN WESTERN SOUTH DAKOTA

A replacement study involving the determination of habitat loss was substituted for the cheatgrass study (FY 1976 NASA Proposal) because of the 1976 drought. Cheatgrasses (Bromus tectorum and B. japonicus) are annual species which efficiently use shallow soil water but are inefficient at obtaining water from deeper soil depths (Cline et al., 1977). Unusual weather (extended dry periods) can prevent the usual fall germination of these invader species (Harris, 1977). Jackson and Haakon Counties, South Dakota experienced extreme drought through the 1976 growing season; this effectively eliminated fall germination of the cheatgrass. Since the high altitude flight coverage took place in the fall, this prevented the project from getting off the ground. Spring field checking also failed to locate or detect appreciable communities of cheatgrass.

The replacement study came about after Game, Fish, and Parks (GF&P) personnel were made aware of Landsat imagery's use in resource interpretations. A decrease in wildlife habitat in Meade County had been qualitatively noted in recent years by the GF&P. In order to more effectively provide wildlife management plans, this loss of habitat needed to be quantified. Landsat's temporal coverage and near-orthographic imagery provided the only tool which could help determine the habitat loss criteria under time and money constraints. The results of this study are as follows.

## INTRODUCTION

Rangeland ecosystems constitute at least 40% of the total surface area of the United States. Contrary to general belief, rangeland or a range ecosystem is not a land use but rather "a kind of land" (Colbert, 1977). Numerous native fauna can successfully coexist with cattle in range ecosystems because of differential diet preferences (Stoddard and Smith, 1955). However, availability and quality of rangeland habitat for wildlife is often dependent on cattle stocking rates (i.e. range condition) and the rate and quality of rangeland loss. Policies of rangeland use (e.g. agriculture, recreation, water harvest, etc.) and intensity of use vary tremendously with public attitudes and economic conditions.

In recent years many range areas in western South Dakota have been converted to croplands. High wheat prices and depressed livestock market in the early 1970's have provided an economic incentive for the cultivation of many rangeland areas. This conversion has been witnessed by numerous individuals, including an example on Landsat temporal coverage (Williamson et al., 1976), but the changes have been noted only in a qualitative manner. The "South Dakota Land Use 1975 Estimates" (Soil Conservation Service, 1976) did list general land-use acreage estimates; but there were no specific data on the actual areas affected. Therefore, a quantitative evaluation (positive or negative) of cultivation within rangeland ecosystems has been impossible. Landsat-based

interpretations can provide the wildlife manager with data of this type for effective management of these valuable resources.

Meade County (figure 7) is a western South Dakota county where such losses have occurred. The county covers approximately 890,000 hectares and has three major surficial geologic formations or sources of parent material (figure 8). The Black Hills encompass only a minor portion of southwest Meade, and since it is forested, only a small amount of open rangeland exists there.

The objectives of this study are: 1) use remote sensing to monitor and quantify habitat conversion (1968-1976) in rangeland ecosystems in Meade County, South Dakota; 2) stratify (or qualify) this data by soil capability units and by rangeland habitat ratings to further indicate potential implications on wildlife population trends, habitat degradation, etc.; 3) cooperate with GF&P in implementing and analyzing the RSI-supplied remote sensing data together with any corresponding GF&P data (see Appendix A); and 4) transfer the techniques (Landsat interpretations) used in this project to GF&P personnel for continued use in trend evaluations and formulation of management policies in this and other rangeland areas.

#### PROCEDURES

Black and white 1968 panchromatic photography (ASCS) in the form of photo-index sheets at 1:63,360 scale was photo-interpreted for rangeland and cultivated areas. These areas were delineated

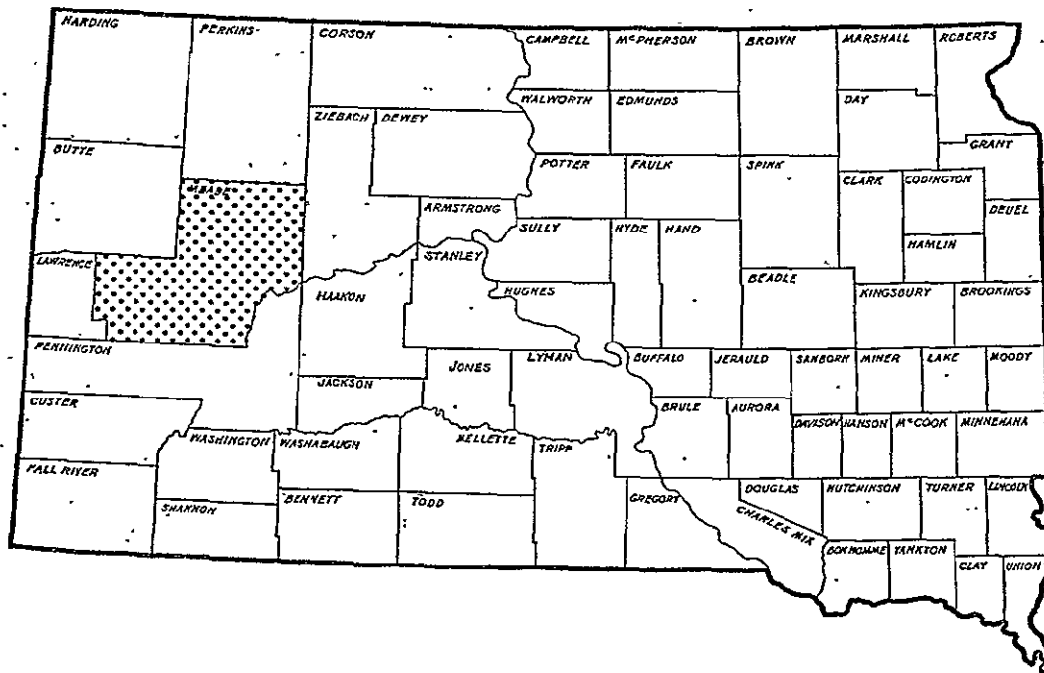
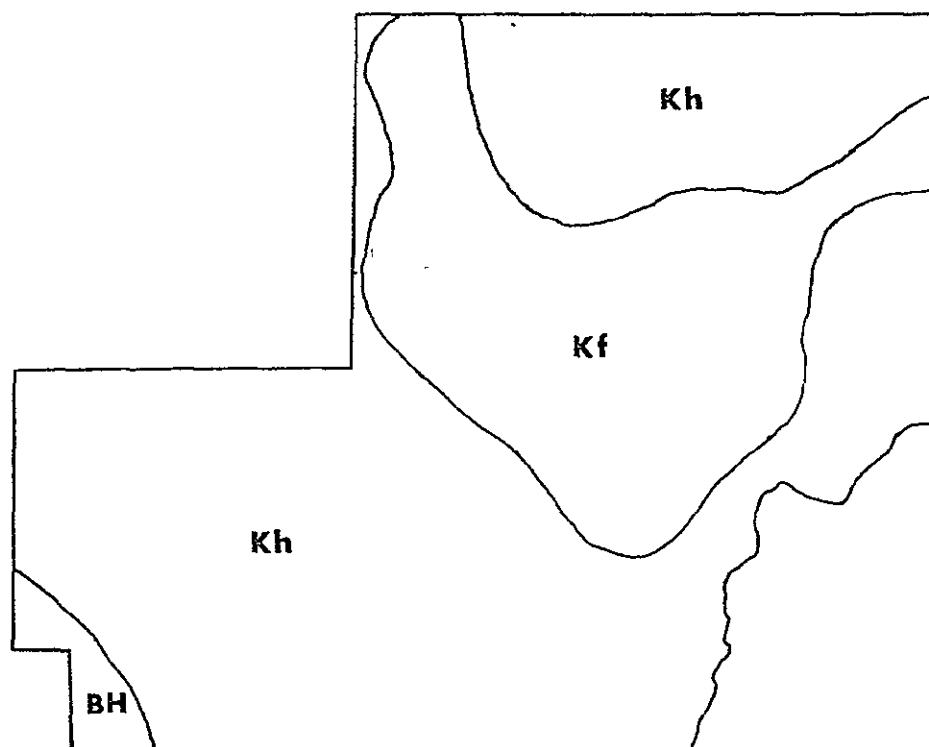


Figure 7. Location of Meade County, South Dakota.



**Kh**--Hell Creek--sandy shales

**Kf**--Fox Hills sandstone

**BH**--Black Hills--undifferentiated crystalline,  
metamorphic and sedimentary materials

Figure 8. Surficial distribution of parent material  
(Westin et al., 1967).

on mylar overlays and then scaled to fit county road maps for east of registration.

Landsat imagery was photo-interpreted to provide 1976 data on the loss of native ecosystems. The imagery was reproduced at the scale of 1:250,000 in the form of a color composite (false color rendition) of bands 4, 5, and 7. Single band data at other dates were also checked. Data from the Landsat survey were rescaled to fit the county road map and 1968 data scale. A composite overlay was developed from the 1968 and 1976 data; south Meade was divided into segments because of its size - east half and west half (figure 9). Figure 10 shows an example of conversion of rangeland to cropland between just 1972 and 1976 on Landsat coverage.

Soil interpretative data were used to stratify the county habitat loss data; the soils data included soil associations, land capability classification, rangeland habitat ratings, and general wildlife habitat groupings. Landsat imagery besides providing various thematic data also provided an excellent base map because of its near-orthographic coverage. The aforementioned data helped determine the quality of the habitat loss. The acreage of State and Federal controlled lands in Meade County were also included; these lands are not subject to cultivation. A series of overlays was prepared from each of the preceding soils data. Each thematic overlay was compared with the composite overlay of habitat loss, and the area loss in each respective theme was measured using an automatic planimeter. The county area was divided into thirteen segments to insure accuracy; also, each segment was planimetered twice.

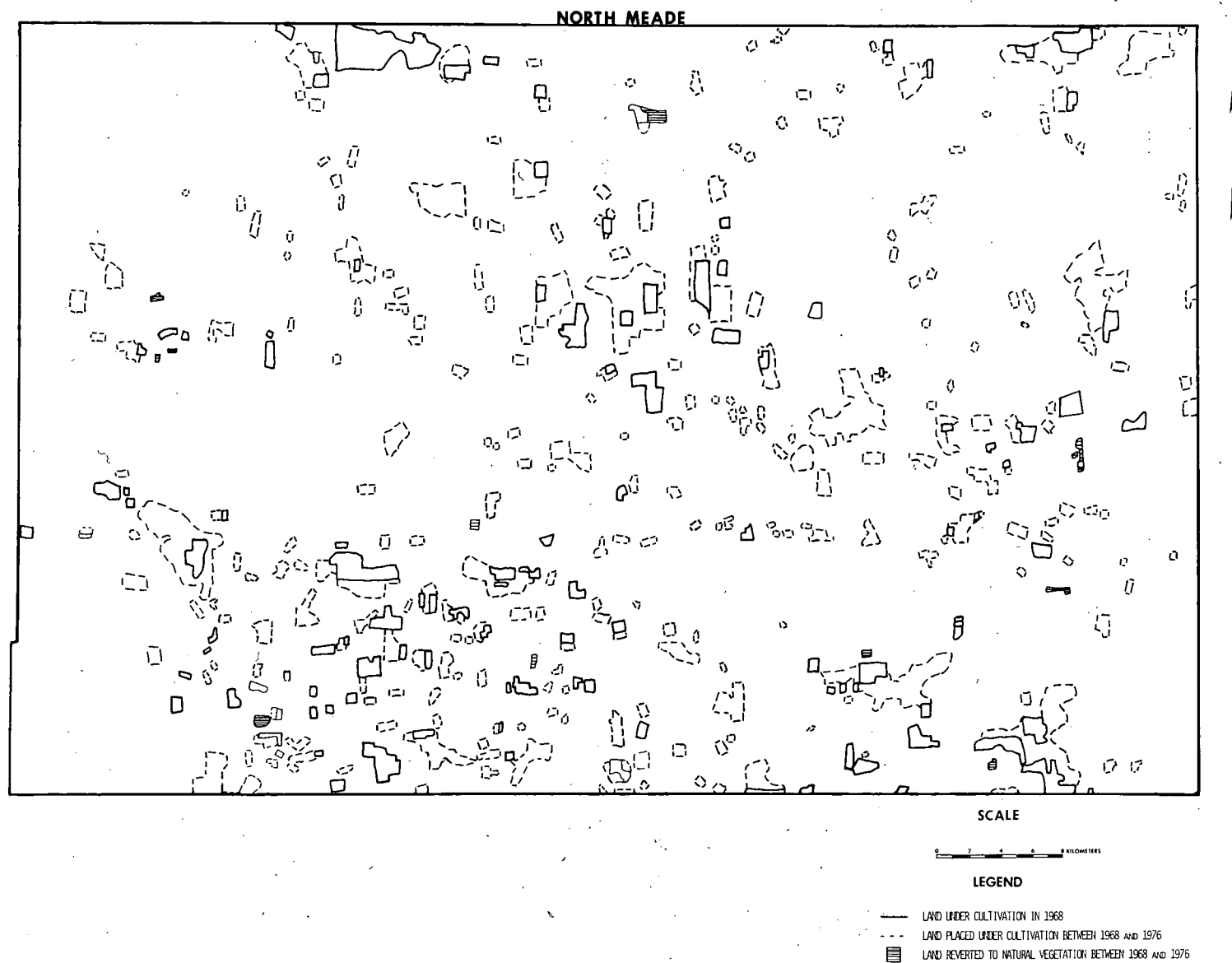


Figure 9. Spatial display of range habitat loss in Meade County, South Dakota.



## WEST HALF

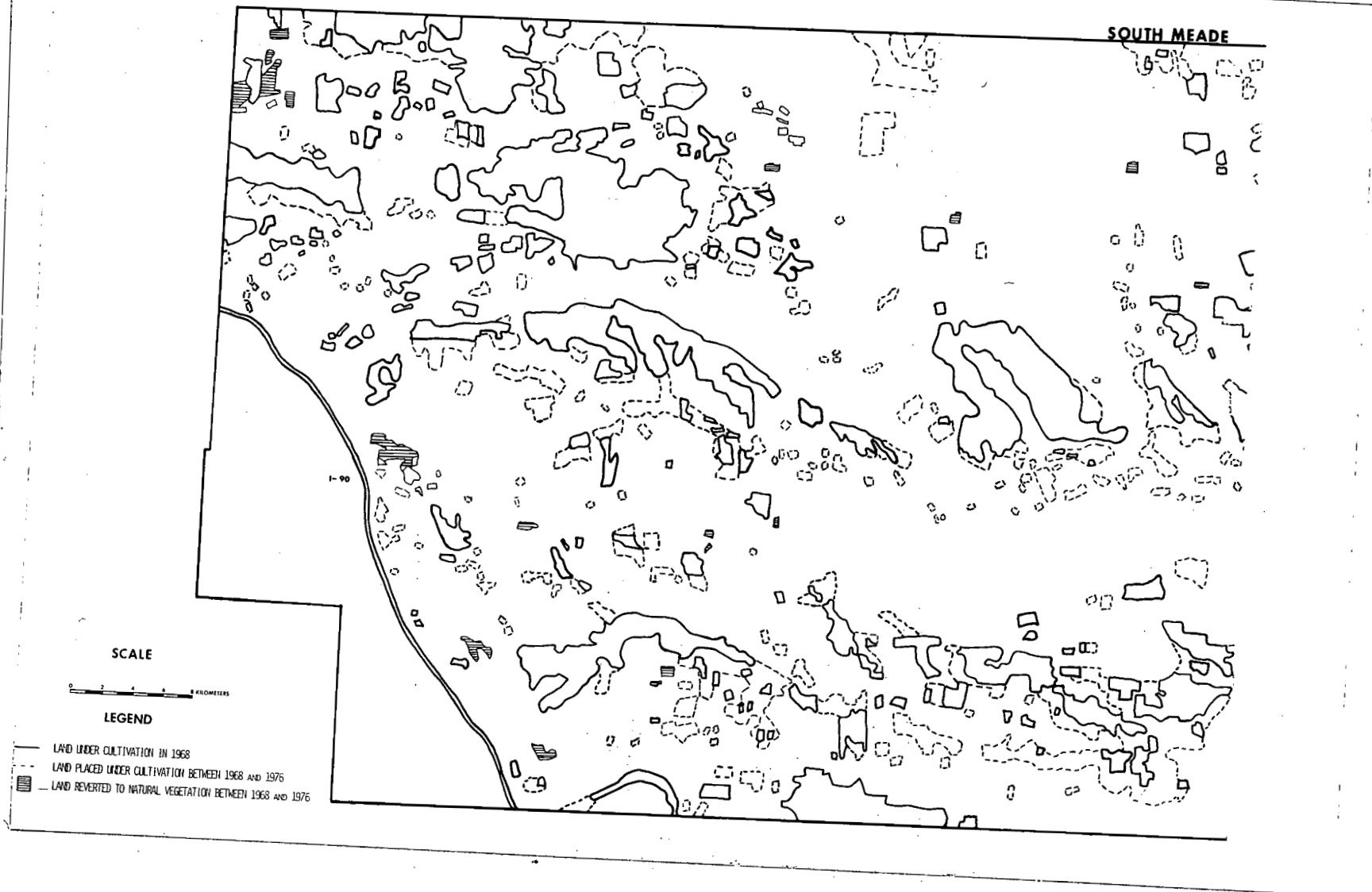
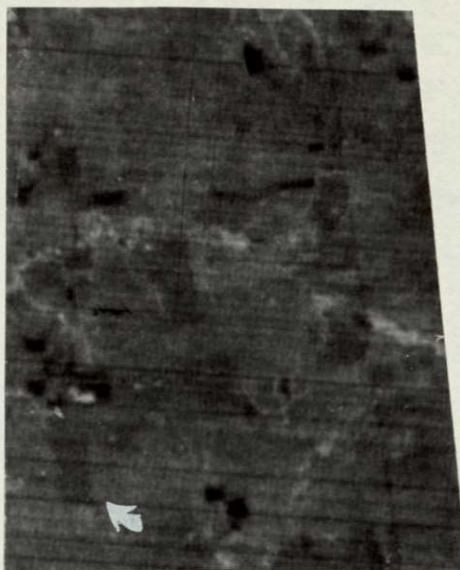


Figure 9 continued.

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SEPT. 1972



MAY 1976



Figure 10. Example of land placed under cultivation between 1972 and 1976 in Meade County, South Dakota as noted by satellite imagery.

## RANGELAND ECOSYSTEM CHANGES

Landsat imagery indicated the diverse nature of soils, slopes, and drainage networks in Meade County. This diversity provides an environment that supplies various requirements needed for wildlife species. This also indicates that the loss of range habitat in one area will not necessarily equate to the loss of a similar acreage in another area. Table 2 lists the habitat losses as stratified by soils and associated parameters. The 1968 analysis indicated 73,000 ha were under cultivation in 1968. Interpretation of the Landsat imagery indicated that over 64,000 ha of rangeland were placed under cultivation between 1968 and 1976. The total for cultivated land in 1976 was over 137,000 ha. The lands managed or owned by State or Federal agencies are not subject to cultivation (table 2, B); this acreage (or rangeland habitat) is managed under prescribed guidelines.

Table 2 lists the soils where the most intensive conversion to cropland is taking place (E). By noting the extent of the particular soil associations (A), it becomes apparent that the cropland increases are not strictly taking place in relation to the size of the soil unit. Selective cultivation is probably taking place in the more arable component soils or in the named or unnamed inclusions. For example, the DY-AZ association is listed as Class VI land (G) because of the DY component; however, the AZ component is Class IV land on 0-6% slopes.

Land capability classification (G) groups soils that have similar restrictions for use. Capability Classes I-IV are suitable

Table 2. Habitat conversion from 1968 to 1976 as stratified by soil association units and other associated parameters.

	(A)	(B)	(C)	(D)
Soil Association	Extent in County (hectares)	State & <sup>1/</sup> Federal Ownership or Management of Lands	Area Under Cultivation in 1968 (hectares)	Area Put Under Cultivation from 1968 to 1976 (hectares)
Assinniboine-Marmarth-Delphill (AZ-M6-DY)	14,952.6	308.3	2229.1	3641.8
Blackpipe-Assinniboine-Savo (B8-AZ-S5)	31,282.2	2443.2	5132.1	4644.1
Blackpipe-Shingle (B8-KI)	18,451.8	855.4	0	355.2
Blackpipe-Savo-Manvel (B8-S5-MD)	33,420.6	1097.1	3499.2	1650.4
Canyon-Lakoa-Maitland (Ca-L6-Me)	12,409.2	854.4	531.3	423.6
Cabbart-Absher (C4-AB)	21,578.4	1403.1	25.9	215.9
Cabbart-Delphill (C4-DY)	35,575.2	1378.8	168.4	1801.8
Delphill-Assinniboine (DY-AZ)	142,429.0	4454.2	4613.7	12366.3
Citadel-Vanocker (E2-VT)	24,640.2	14401.9	0	0
Grunmit-Pierre (GW-PK)	13,948.2	682.9	933.1	947.7
Kyle-Pierre-Hisle (KR-PK-HN)	76,010.4	11139.2	4095.3	7206.6
Lohmiller-Glenberg (LR-GD)	45,036.0	1681.0	3447.4	8564.9
Nunn-Satanta-Zigweid (N6-JT-ZC)	107,308.8	6026.5	37195.2	9081.7
Regent-Marmarth-Cabbart (RG-MG-C4)	13,446.0	326.0	2358.7	1662.1
Samsil-Lismas-Pierre (SB-LN-PK)	110,160.0	14588.1	2384.6	3294.7
Stetter-Arvada (S3-AU)	9,007.2	924.9	181.4	482.4
St. Onge-Keith (SY-KH)	17,998.2	136.4	5184.0	845.6
Tilford-Nevee (TU-NC)	8,035.2	1054.6	51.8	130.0
Twilight-Absher (TY-AB)	124,302.6	5469.0	1088.6	5329.4
Winler-Lismas-Swanboy (WU-LN-SW)	45,230.4	3022.3	259.2	1628.9
Totals	905,222.2	72247.3	73379.0	64273.1

<sup>1/</sup> This includes Forest Service, BLM, G, F & P, and State school lands.

<sup>2/</sup> Other land capabilities may occur within each soil association. Percentage composition of each major soil is the major determinant of the capability unit.

<sup>3/</sup> Known compositions and interpolated compositions of the soil association data approximates the acreage loss of good rangeland habitat at 33,400 ha (52%), fair habitat at 24,000 ha (38%), and poor habitat at 6,600 ha (10%).

Table 2 continued.

(E)	(F)	(G)	(H)
Ranking (by ha) of Habitat Loss, 1968 to 1976 Period	Total Area Under Cultivation 1976 (hectares)	Dominant Land <sup>2/</sup> Capability Unit (Class is 'e' unless other- wise noted)	Rangeland <sup>3/</sup> Habitat Suitability
7	5870.8	IV	Good, Good, Fair
6	9776.3	IV	Good
17	355.1	IV	Fair
11	5149.5	IV	Good, Good, Fair
16	954.9	VI	Good, Good, Fair
18	241.7	VI	Fair, Poor
9	1970.3	VI	Fair
1	16980.0	VI	Fair, Good
20	0	VI	Very Poor
13	1880.8	VI	Fair, Good
4	11301.9	VI	Good, Good, Poor
3	12012.3	III	Fair
2	46276.9	IV	Good, Good, Fair
10	4020.8	IV	Good, Good, Fair
8	5679.3	VI	Fair, Poor, Good
15	663.8	IV s	Fair, Poor
14	6029.6	III	Fair, Poor
19	181.8	IV	Good, Fair
5	6418.0	VI	Good, Poor
12	1888.0	VI s	Poor
	<u>137651.8</u>		

for cropland under varying levels of management. Class IV is very severely limited for crop production and requires intensive management practices. Classes V-VIII are best left in their native state because of severe restrictions. The major subclass of Meade County soils is 'e' which indicates a susceptibility to wind and/or water erosion. The other subclass is 's' which indicates a soil limitation; in this case it is natric horizon or claypan which restricts root growth and moisture infiltration.

Rangeland ecosystems vary in capability to support wildlife depending in part on the underlying soil strata. Certain soils, by value of landscape position, fertility, depth of solum, etc., provide the diversity of cover, food, and general environment necessary for wildlife species. Therefore, present efforts include overlaying the Landsat data that indicates where rangeland losses have occurred with soils data to better qualify the value of the ecosystem loss. This will also provide a basis for judging increased erosion potential, range site quality, and the relative value of lost habitat.

Soil ratings for rangeland wildlife habitat (table 2, H) are based on the ease with which habitats can be established, improved or maintained. The best suited soils contain few or no limitations in habitat management. As habitat ratings decrease, the feasibility of establishment and improvement of habitat lessens due to soil restrictions. By using known soil compositions and interpolating the unknown compositions of the soil association units, the hectareage

of habitat quality was approximated 33,000 ha of good, 24,000 ha of fair, and 7,000 ha of poor habitat that were cultivated (or lost) between 1968 and 1976.

Native range habitat is a fixed physical resource. As pressure from various interests encroaches on this resource, managers must be aware of the actual extent and quality contained within specific habitat areas. 'Solid' data are needed by the managers when interacting with various other interest groups. If the wildlife manager has data of this sort, effective management, establishment, construction, and maintenance of quality habitat can take place (see Appendix A).

#### SUMMARY AND CONCLUSIONS

Landsat data demonstrated its utility in the resource planning field. Landsat data provided the means of establishing baseline information that was integrated with other data (soils, vegetation, etc.) in the establishment of wildlife management plans and determination of habitat loss trends.

Landsat data were incorporated with other aerial photography (ASCS) to delimit rangeland habitat losses in Meade County between 1968 and 1976. Overlays were set at the same scale as county road maps to facilitate ground checking and to provide ease of location by the users (GF&P). These data and ancillary data are included in the following listing of Meade County data supplied to GF&P personnel.

1. 1968 overlays of range and cropland interpreted from ASCS aerial photography.
2. 1976 overlay of range and cropland interpreted from Landsat imagery.
3. Integration of 1) and 2) into a composite overlay indicating areas of intensive conversion (see table 2 and figure 9).
4. Overlays of soil interpretative data (see table 2 for listings and hectare age) which helped to qualify the habitat conversion.

The remote sensing data supplied to GF&P personnel will be incorporated with GF&P wildlife data to analyze trends and develop management plans. Associated parameters of concern together with habitat loss are big game population changes from 1968 and any factors which may influence these changes such as: climate, predator numbers, hunter permits, livestock populations, and disease. Landsat imagery provided a quick and inexpensive means of establishing quantitative baseline data which can be used in the integration of the numerous variables that must be considered when establishing habitat management procedures.



## REFERENCES

- Cline, J.F., D.W. Uresk, and W.H. Rickard. 1977. Comparison of soil water use by a sagebrush, bunchgrass and a cheatgrass community. *J. Range Manage.* 39(3): 199-201.
- Colbert, F.T. 1977. Land use planning - a summary from the rangeman's point of view. *Rangeman's J.* 4(30): 74-76.
- Harris, G.A. 1977. Root phenology as a factor of competition among grass seedling. *J. Range Manage.* 39(3): 172-177.
- Soil Conservation Service. 1976. South Dakota land use - 1975 estimates. Huron, South Dakota.
- Stoddart, L.A., and A.D. Smith. 1955. Range management. 2nd Edition. McGraw-Hill Book Company, New York, N.Y.
- Westin, F.C., L.F. Puhr, and G.J. Buntley. 1967. Soils of South Dakota. Soil Survey Series No. 3, S.Dak. Ag. Exper. Sta., Brookings, South Dakota.
- Williamson, E.J., E.A. Dowding, W.A. Aanderud, G.R. Durland, F.J. Shideler, M.S. Argabright, and A. Griffiths. 1976. Conservation tillage. Coop. Exten. Service, SDSU, USDA Bull. EC 703.

## APPENDIX A



## Department of Game, Fish and Parks

40

### Division of Game and Fish

3305 West South Street  
Rapid City, SD 57701  
PHONE: 394-2391

July 28, 1977

Kevin Dalstad  
Remote Sensing Institute  
South Dakota State University  
Brookings, SD 57006



Dear Mr. Dalstad:

I am writing to inform you on the various ways we have been using the photo products from the Remote Sensing Institute. This material has been quite useful and we have been able to begin incorporating it into our decision-making processes in this region.

As you know, there has been increased use of rangelands in this area for cultivation. Our conservation officers, biologists and staff have noted that this change in uses of land may have been having an effect on the wildlife resources in this region. Recent publications of the Soil Conservation Service contained data that was very disturbing to the wildlife professionals in the region.

South Dakota Land Use - 1975 Estimates - provided data that concerned the field officers and stimulated this office to begin searching for ways to evaluate the effects this rapid conversion of rangeland to cropland was having or might have on the wildlife habitat and populations of the region. It was obvious from the first that none of the field personnel would have the time to research the changes on the ground. The changes that had occurred from 1967 to 1975 were of such a large magnitude that to do anything more than a cursory field check would require more time and manpower than existed in the Department. We had cooperated in other projects with RSI and were somewhat familiar with the materials that you could provide.

The quantitative data that existed regarding the changes in rangeland and cultivated lands were estimates at best, and did not lend any further information beyond the most basic.

To determine what impacts this conversion would have, we needed a method of gathering quantitative data that would provide us with more accurate picture of what was happening.



Kevin Dalstad  
Page 2  
July 28, 1977

Because Meade County is the largest county in the region, has a representative mixture of rangeland and cropland, and had been studied by RSI for other agencies; it was decided to use this county as a test area to determine if RSI data products and technology would provide useful information to evaluate the impacts.

The impacts we consider most important are effects on available wildlife habitat, erosion of soils and loss of grazing lands.

The term wildlife habitat is a general term that means many different things. Our thoughts were to be able to readily identify the plant communities that occur on the soil types in Meade County, evaluate these plant communities for the types of wildlife that would normally be found on them and then relate the loss of these plant communities to the wildlife populations. Each of these soil types also had different erosion characteristics. The eroded soil, carried by wind or water eventually ends up in wildlife water supplies and can dramatically change the quality of these water supplies. In addition, the stream and river water quality would be impacted to various degrees and have fisheries management implications. Rangeland provides the carrying capacity for most of the big game animals of the prairie. Mule deer, whitetails and antelope are all important species that will be impacted if this resource is lost.

As you can see, there were many impacts that concerned us when we found out that rangeland conversion was taking place at a rate of 25 percent decrease in eight years.

Through the present project we hope to find out if RSI technology will allow us to predict the losses that may be occurring and to make management decisions that will allow us to mitigate or prevent those losses.

To assist us we have asked for a series of overlays identifying the areas under cultivation in 1968, those under cultivation in 1976, the soil types in Meade County, the soil capability classes in Meade County and surface water areas in Meade County. These overlays, scaled to fit present county highway maps, will be used in the following ways.

Antelope and deer kills will be plotted on county highway maps. Results of the 1968 and 1976 pheasant and grouse surveys will be plotted on the county highway maps. Aerial survey results from 1968 and 1976 will be plotted on the county highway maps. These maps will then be overlayed with the soil overlay, the cropland overlay and the soil capability class overlay. Interpretation of these maps will be done to see if there is any correlation between the results of our survey data, harvest data and present ground truth and the rangeland conversions that have been done. It is hoped that through these interpretations, we will be able to identify areas of critical wildlife habitat that may be in danger of conversion to cropland, if there are any public lands that may be managed differently to mitigate changes in rangeland to cropland and to determine management considerations for the remaining habitat that is available.

Kevin Dalstad  
Page 3  
July 28, 1977

Presently Larry Stomprud, conservation officer in Wall, South Dakota, is using high altitude data to plan another grouse reproduction survey. He is using historical data to evaluate the changes that have occurred on the established routes in another area to see if he can determine any relationship between the change in rangeland conversion to the changes in the observed grouse population.

There may be other information available through the interpretation of the technology and data products that you will provide, and we will attempt to use any of this information to assist us in our management decision-making processes.

We have used RSI data products in several other ways not necessarily related to this specific project as well. A 1976 image of some state-owned lands in the Spearfish area assisted our Commission in understanding the value of certain lands located along a traditional deer migration route. These lands were offered for sale to the general public as recreational home development sites. The threat to management of one of our most critical deer winter areas was very great and we had a difficult time in convincing the Commission to purchase these lands. I am most happy to report that through our efforts and the imagery provided by RSI, we were able to convince the Commission of the value in purchasing this important tract of land. We have made an offer on these lands and will soon be managing them for wildlife.

We are encouraged by the usefulness of the RSI technology and data and will continue evaluation of this data and its usefulness in our management decision-making. As we learn more about the RSI and the technology, we would expect to be able to use these to our advantage whenever possible and feasible.

Sincerely,



Ted E. Schenck  
Assistant Regional Supervisor

TES/dmh

## THE USE OF REMOTE SENSING TECHNOLOGY TO MAP ASPEN

### INTRODUCTION

For the past three years the South Dakota Department of Game, Fish, and Parks has been involved in the study of the management potentials of aspen within the Black Hills. The main focus of the study is on the management of aspen for improved wildlife habitat, especially for ruffed grouse. Through experimental cutting, portions of decadent aspen stands are removed, generating a new cycle of growth. The interaction of mature stands of aspen and the areas of new growth provide excellent habitat for ruffed grouse and other wildlife.

Game, Fish, and Parks personnel have also been involved in a research study which evaluates aspen as a food source for livestock. Tests have shown that food rations containing processed aspen were superior to an alfalfa control ration in daily gain and feed required per pound of gain (Kamstra et al). Preliminary results indicate that processed aspen could serve as a major food component if its nutritional deficiencies are corrected.

Knowledge of the location of aspen stands is absolutely necessary for the improved management of wildlife habitat and potential industrial harvesting of aspen as a livestock food source. Preliminary aspen delineation studies conducted under NASA Contract NAS5-20982 indicate that aspen maps generated from digital analysis of Landsat CCT's are more accurate than existing U.S. Forest

Service maps (Schmer et al., 1977). Continued Landsat digital analysis will develop and refine the methods used for mapping aspen.

#### STUDY AREA

The Black Hills are located in western South Dakota and eastern Wyoming along the South Dakota-Wyoming border. The Black Hills are composed of deciduous and coniferous forest with intermingled grass meadows. The major conifer type is ponderosa pine and the major deciduous type is aspen.

Over the last 75 years the forest has become over stocked with pine. This is due primarily to the prevention of forest fires and the limited logging activity. The pine has overwhelmed many of the aspen stands and meadows. Consequently, there has been a severe loss of wildlife habitat.

#### PROCEDURE

The primary data source for mapping aspen is the Landsat digital data. Three software systems are being utilized to perform the analysis. Landsat Imagery Analysis Package (LIMAP) software is being used to display the raw data, train the classifier, and categorize the study area. LIMAP utilizes a Gaussian maximum likelihood classification algorithm (Tessar and Eidenshink, 1976). Digital Image Rectification System (DIRS), a NASA provided software package, is being used to perform geometric correction of the classified data to a Universal Transverse Mercator (UTM) grid system (Van Wie et al., 1975). Ground control points (GCPs) that can be easily located on reference maps and

greytone printouts of raw data are selected and used to determine the geometric correction factors. Once the data are corrected, pixels corresponding to UTM coordinates can be easily located. This allows for extraction of selected areas for further analysis. The third software package, K-Class, is also being used to classify the data. K-Class is a supervised non-parametric classifier. The results of the K-Class and LIMAP classification are being evaluated for cost effectiveness and reliability.

The secondary data source is high altitude color infrared photography obtained through NASA Contract NAS5-20982 and NASA Grant #42-003-007. In order to provide two comparable data sets, the high altitude photography was collected within two weeks after the Landsat scene which is being analyzed.

The primary ground truth data used was high altitude photography. Enlargement prints at a scale of 1:24,000 were made of test areas and interpreted with the assistance of Game, Fish, and Parks personnel. The process involved the interpretation of six categories: water, grass, pine, pine predominant over aspen, aspen predominant over pine, and aspen. The four forest categories were based on the amount of each tree type present. Pure stands are areas where aspen or pine is in excess of ninety percent of all tree types present. Areas where aspen or pine was in excess of fifty percent but less than ninety percent was considered a predominant stand.

After the ground truth data were obtained, training sample coordinates corresponding to the ground truth were located on a



rectified MSS 7 level sliced greytone printout of an area of approximately one-half million pixels. The training sample coordinates corresponding to the available ground truth data as well as additional training samples were used to ensure that all variations of each spectral class were included. The coordinates were input to the maximum likelihood classifier. The total sample pixels were approximately 2% of the total area to be classified.

Category definition (clustering) is the most important step in developing the classification. The optimum situation would be the definition of spectral classes which clearly represent the land use categories present. In most instances there is confusion between border pixels of similar spectral classes. The degree of confusion determines the reliability of the classification.

A successful method of eliminating a great deal of the spectral confusion is to cluster for an excessive number of classes. When an excessive number of classes are defined the areas of confusion are subdivided into several small classes. A very simplified illustration of the theory is in figure 11. In addition to the confusion areas being divided it is possible the classes that have no confusion will be subdivided. This very seldom poses any problems because the subdivisions are so closely related that they can be statistically merged back into one category. It is imperative that the unnecessary subdivisions be merged together

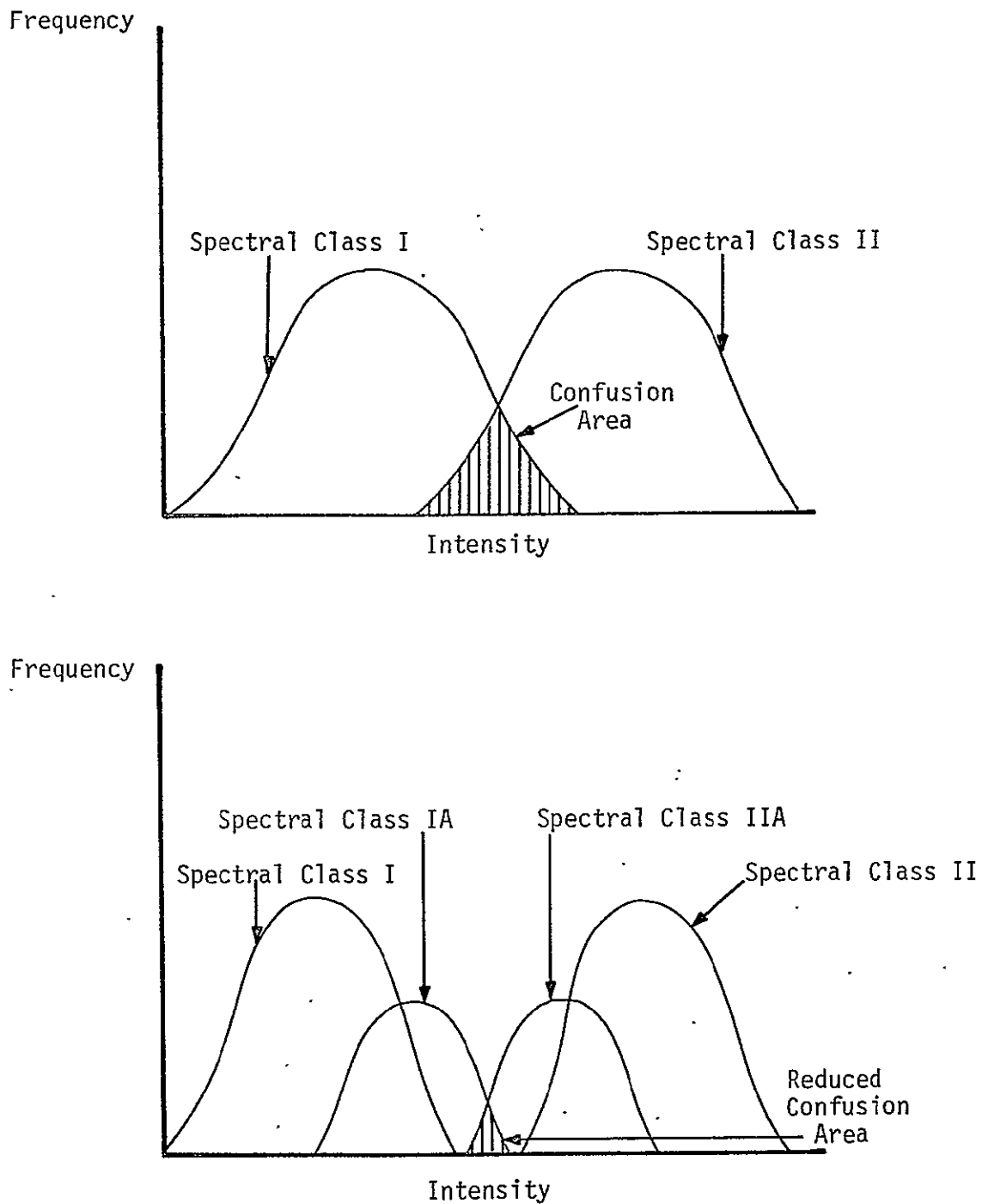


Figure 11. Illustration of reduced class confusion as a result of excessive class definition.

in order to reduce the amount of calculations that will be performed when the entire study area is finally classified. This procedure significantly reduces computer costs. The remaining small confusion classes are thematically combined with the distinct spectral classes they most closely represent during the mapping process.

During clustering fourteen spectral classes were defined. After comparing the cluster results to the ground truth it was determined that there was still a great deal of confusion between some classes. The greatest confusion existed between the aspen and grass categories. When such confusion exists it is usually due to a poor training sample. The first training sample selected did not represent enough variation between spectral classes. The variation is caused by circumstances such as soil, age of vegetation, plant vigor, etc. Consequently, a second training sample was selected.

With the second training sample, clustering again defined fourteen spectral classes. After comparison with the ground truth data it was evident that the previous class confusion had been greatly reduced. The classification was then tested in several areas to ensure that the classification was applicable to areas where no training samples had been selected. Comparison with ground truth proved that the classification was representative throughout the study area (figure 12, 13, 14, 15, 16, 17). As in studies performed under NASA Contract NAS5-20982, the Landsat digital classification and the high altitude visual classification

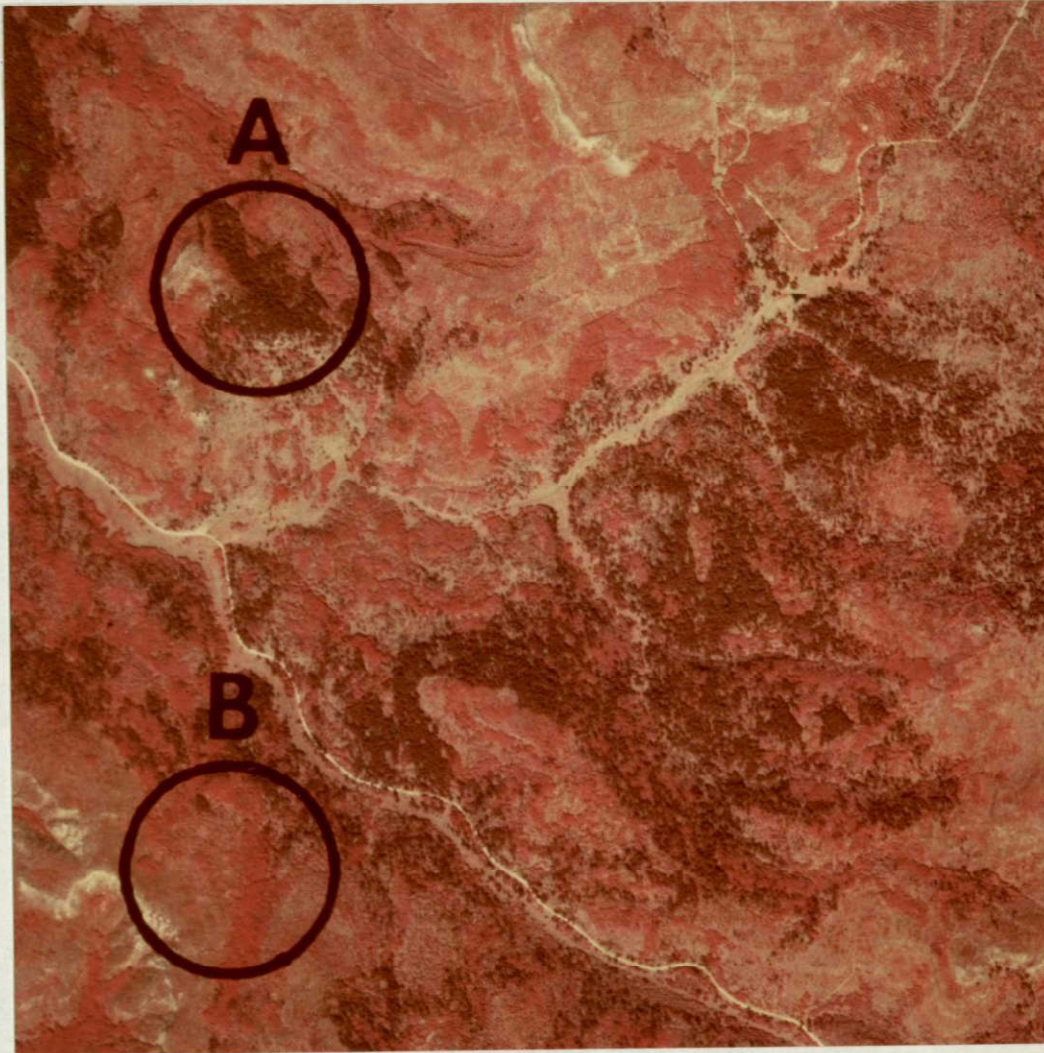


Figure 12. High altitude color infrared photograph of portion of test area 1 corresponding to digital classification in Figure 13. Scale = 1:24,000 approx. Note stands A and B.



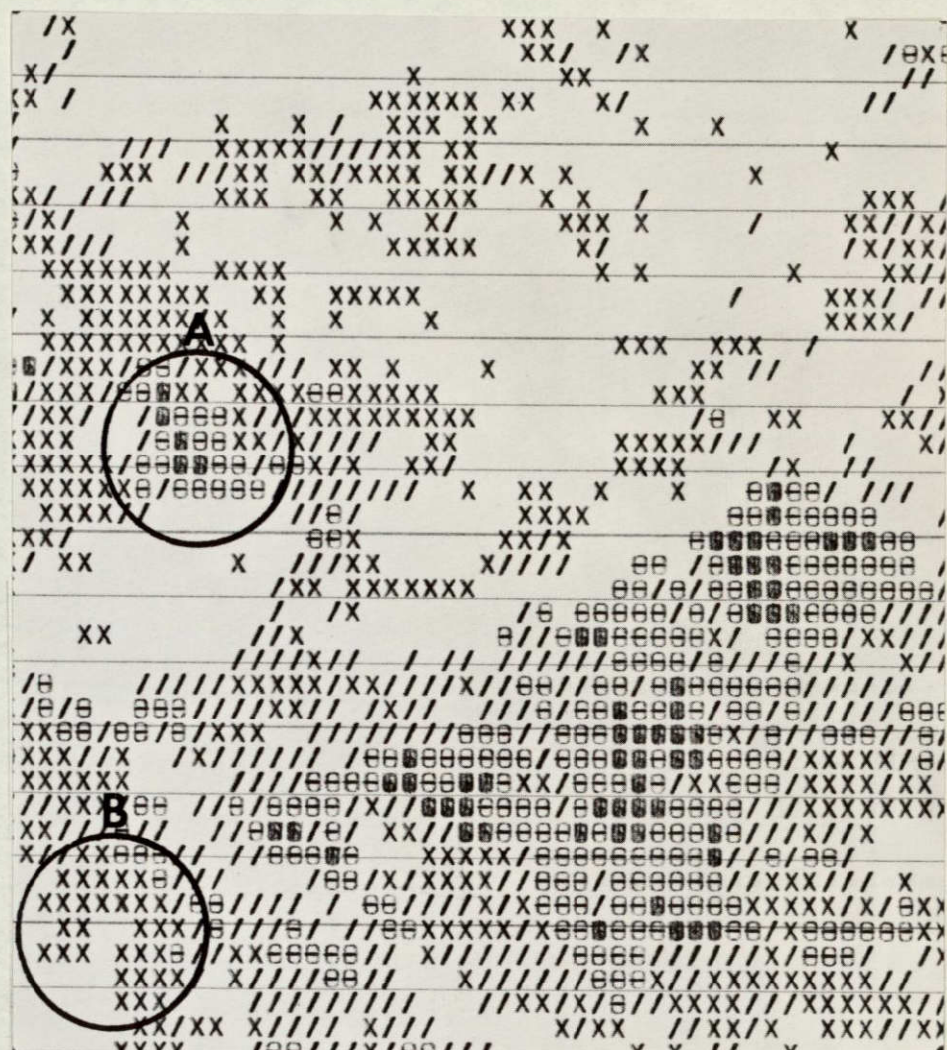


Figure 13. Digital classification of portion of test area 1.  
 Scale = 1:24,000 approx.  
 Legend: w = water, Ø = pine, θ = pine/aspen,  
 / = aspen/pine, X = aspen, blank = grass.  
 Note stands A and B.

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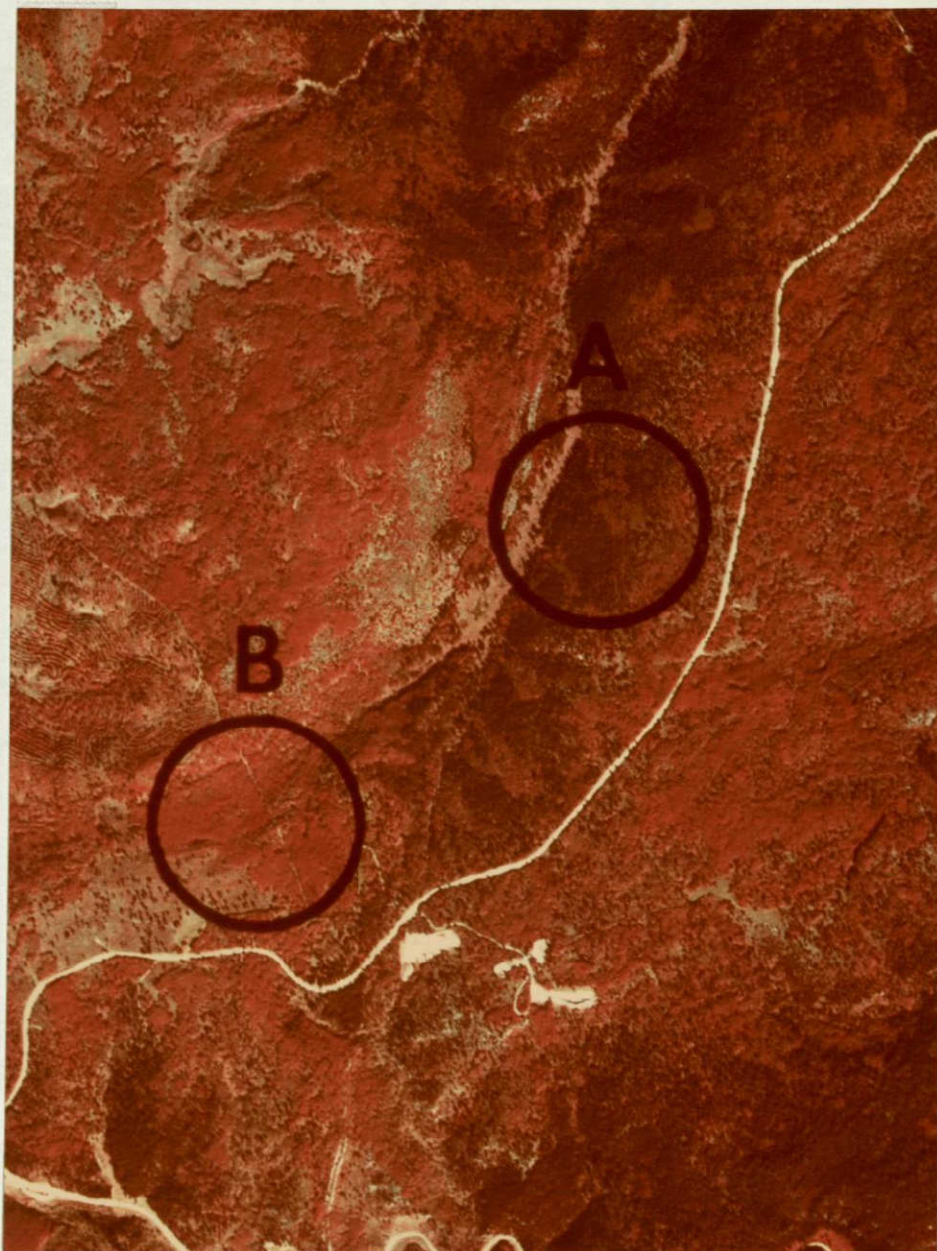


Figure 14. High altitude color infrared photograph of portion of test area 2 corresponding to digital classification in Figure 15. Scale = 1:24,000 approx. Note stands A and B.





Figure 15. Digital classification of portion of test area 2.  
 Scale = 1:24,000 approx.  
 Legend: 2 = water, 0 = pine, θ = pine/aspen,  
 / = aspen/pine, X = aspen, blank = grass. Note  
 stands A and B.



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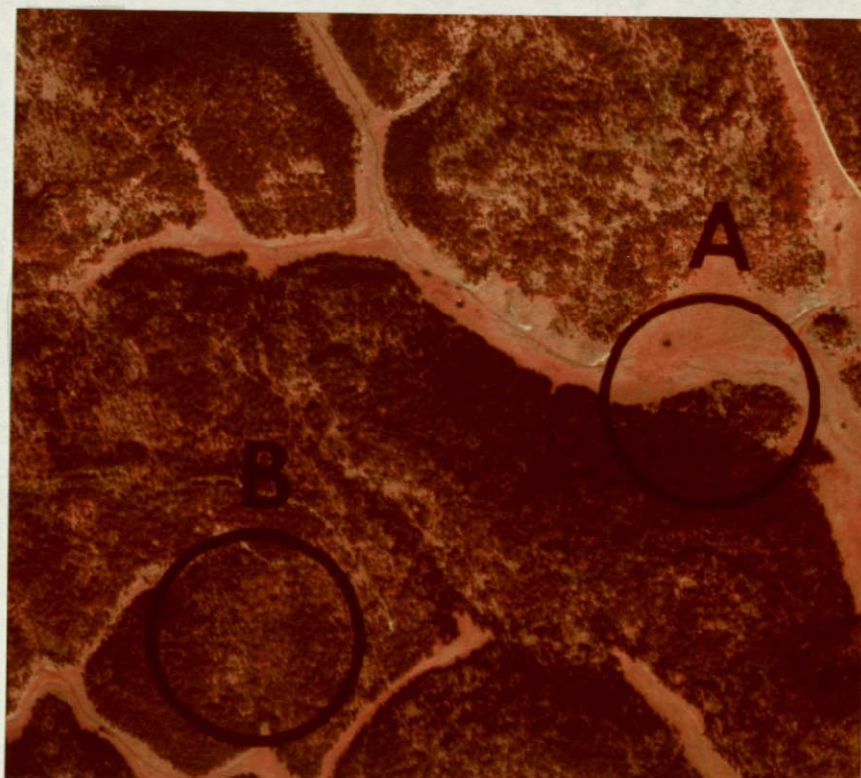


Figure 16. High altitude color infrared photograph of portion of test area 3 corresponding to digital classification in Figure 17. Scale = 1:24,000 approx. Note stands A and B.



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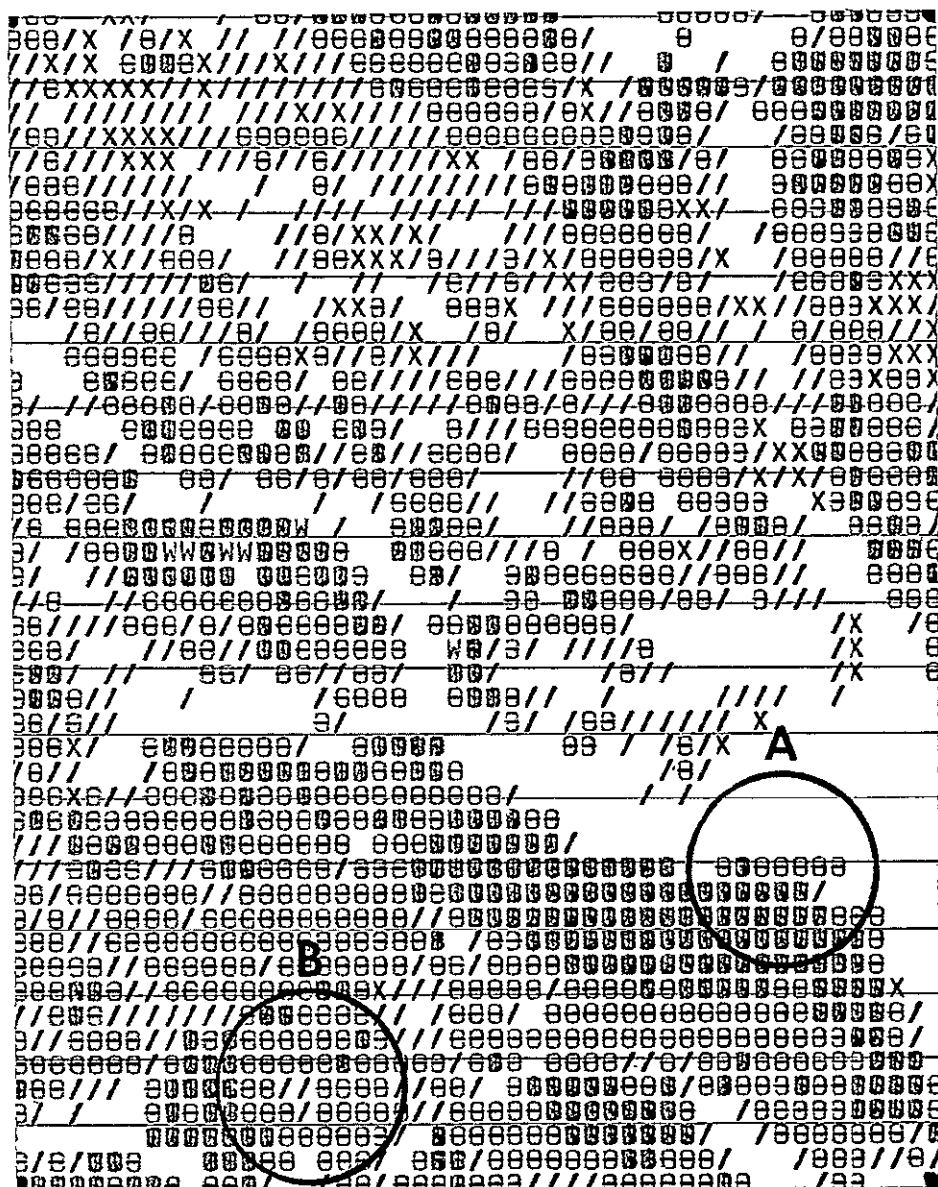


Figure 17. Digital classification of portion of test area 3.  
Scale = 1:24,000 approx.  
Legend: w = water, @ = pine, / = pine/aspen,  
/ = aspen/pine, X = aspen, blank = grass.  
Note stands A and B.

were much more representative of forest types than the existing U.S. Forest Service type maps (figure 18, 19, 20).

In the final analysis it was determined that some of the additional spectral classes were merely sub-classes of categories which are easily defined and did not represent confusion areas between two classes. These spectral classes were statistically merged into the major classes using a statistical file editor program. Of the fourteen spectral classes three were closely related classes of pine and three were closely related classes of grass. Statistical merging of these related classes brought the total number of classes to nine. Separate spectral classes represented pine, water, pine predominant over aspen, and aspen predominant over pine, two spectral classes representing aspen, and three spectral classes representing grass.

If the analyst is not careful during the statistical merging, confusion can be introduced back into the classification. Several areas were tested to determine if any confusion had been introduced. Results showed no major changes occurred in the classification. However, because the number of classes had been reduced to nine, fewer calculations were necessary during classification and consequently, the computer costs were decreased 33%. The classes which could not be statistically combined were thematically combined during the mapping process.

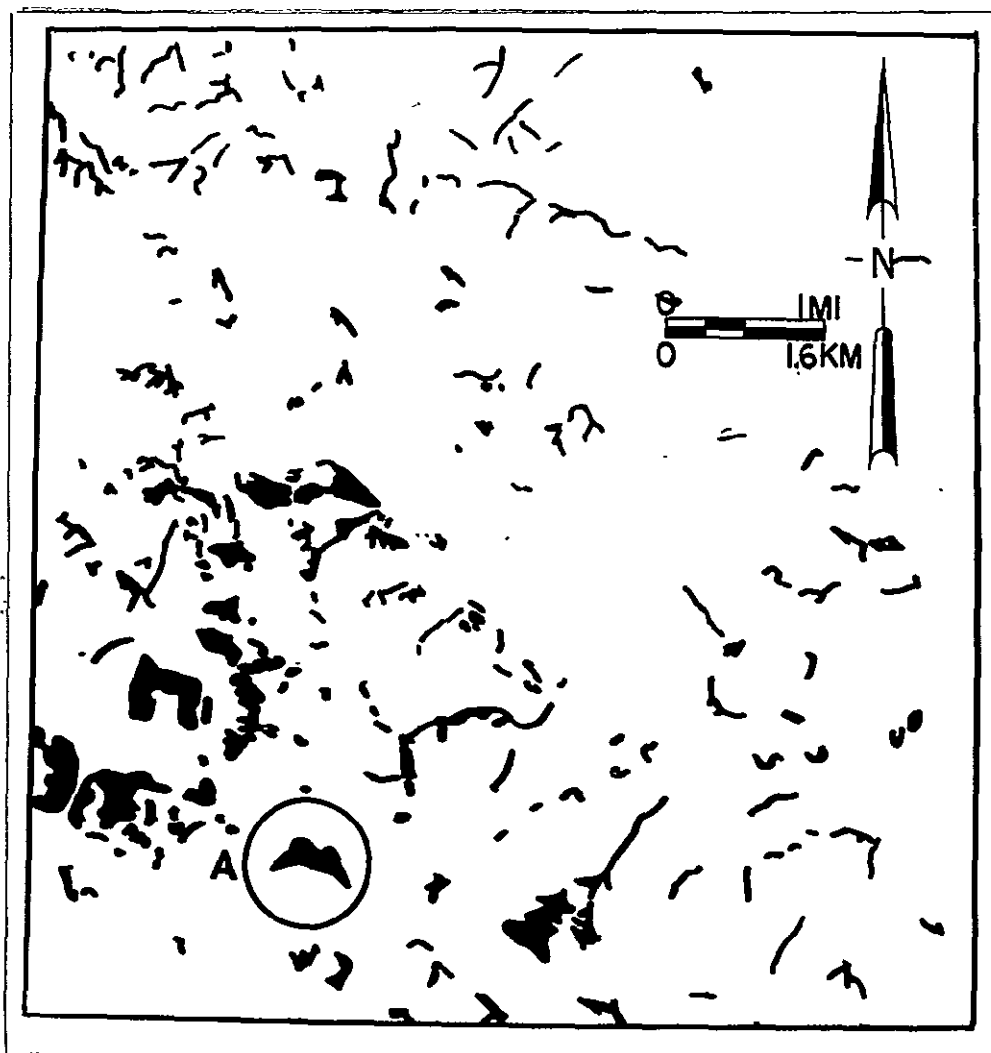


Figure 18. High altitude color infrared imagery of township T4NR5E as interpreted for aspen. Note stand "A" and numerous small aspen stands.

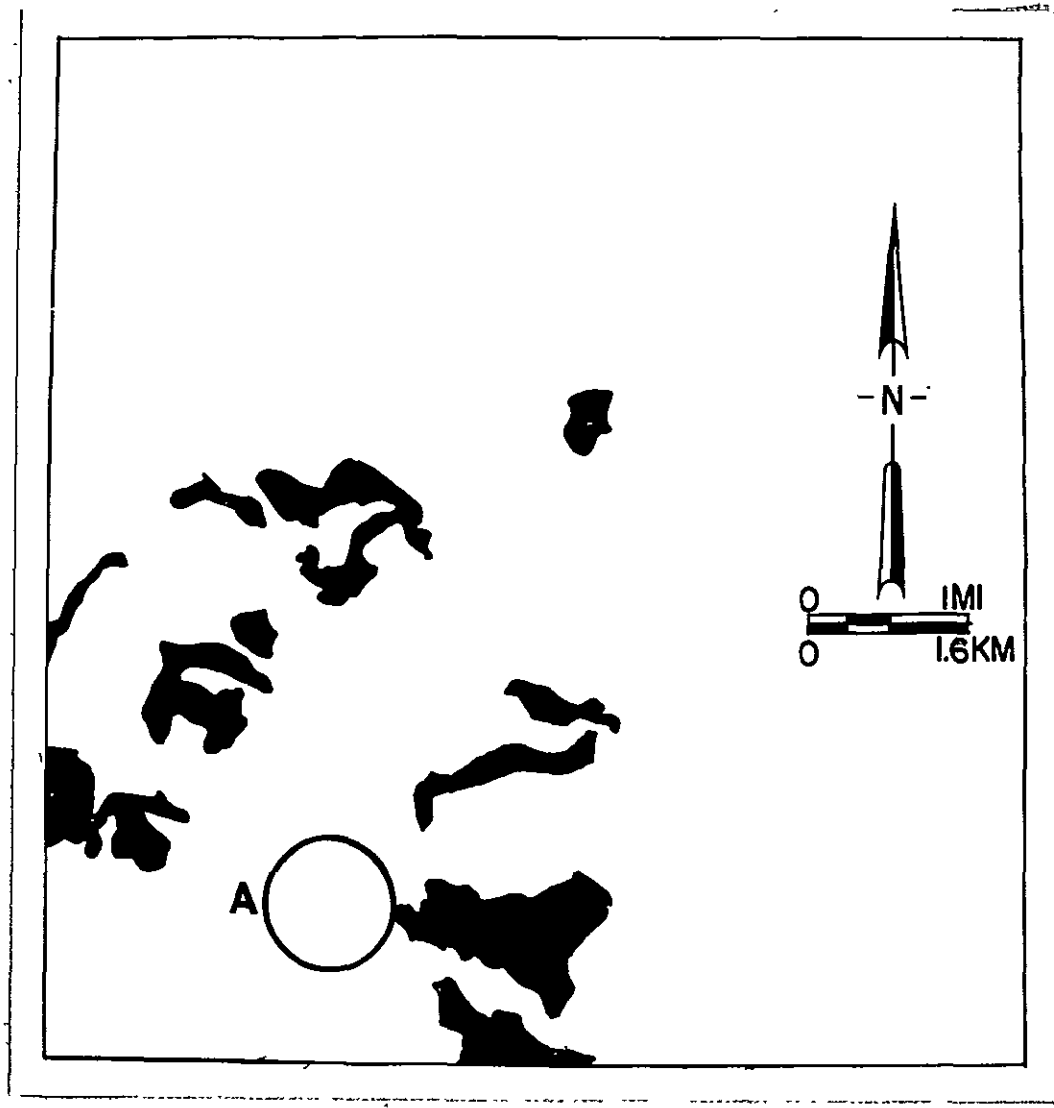


Figure 19. Aspen data from U.S. Forest Service map of township T4NR5E. Note the absence of stand "A" and the lack of smaller aspen stands throughout the area.

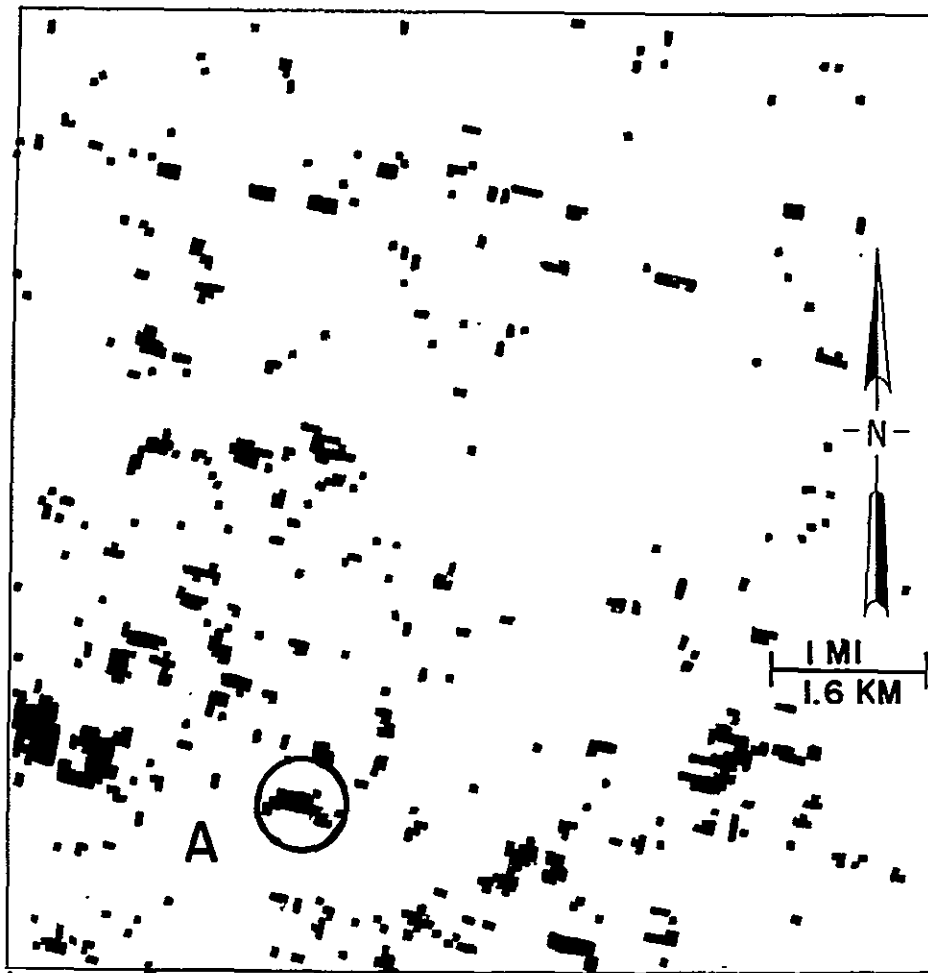


Figure 20. Digital classification of aspen for township T4NR5E using Landsat CCT data. Stand "A" is easily recognized.

## CONCLUSIONS

Results indicate that a satisfactory classification has been developed. The remaining analysis is the completion of the classification of the entire Black Hills and the geometric correction of the data using DIRS. Line maps of areas corresponding to U.S.G.S. 7 1/2 minute quadrangles will be extracted from the data using DIRS. The areas will be plotted at a scale equivalent to the U.S. Forest Service type maps (1:31680) and redrafted creating color coded maps. All spatial and statistical information will be coded into a data management system which will permit map updating, aggregation of data, and special handling as required.

## SUMMARY OF PROGRESS

The development of the classification for delineating aspen in the Black Hills is near completion. Procedures have been developed to classify and assess the data as required. Comparison of LIMAP and K-Class classification procedures will be made to determine the cost effectiveness and reliability of each. Results indicate that the classification will provide a useable inventory for resource management purposes. The South Dakota Game, Fish and Parks has plans to use the inventory, as soon as it is available, in the development of a comprehensive wildlife habitat management plan for the Black Hills area. Documentation of the impact of the inventory will be forthcoming in the FY 79 report.

## REFERENCES

- Kamstra, L.D., L.B. Embry, and M. Singh. 1975. Utilization of Aspen Tree Material as a Ruminant Feed Component. South Dakota State University Experiment Station. Brookings, South Dakota 57006.
- Schmer, F.A., R.E. Isakson, and J.C. Eidenshink. 1977. Investigation of Remote Sensing Techniques as Inputs to Operational Resource Management Models. Type III Final Report. SDSU-RSI-77-05. Remote Sensing Institute, Brookings, South Dakota 57006.
- Tessar, P.A. and J.C. Eidenshink. 1976. Landsat Imagery Analysis Package: Automated Land Use Classification and Multidimensional Geographic Analysis. Proceedings 2nd Annual William T. Pecora Memorial Symposium, Sioux Falls, South Dakota.
- Van Wie, P., Mr. Stein, E. Puccinelli, and B. Fields. 1975. "Digital Image Rectification System Preliminary Documentation." Information Extraction Division, Goddard Space Flight Center.

## HYDROGEOLOGIC APPLICATIONS OF THERMAL IMAGERY

## Black Hills Study

Thermal imagery (predawn and daytime) was obtained on September 10 and 11, 1976, for selected areas in the Black Hills using a Daedalus quantitative thermal scanner in an aircraft flown at an altitude of  $\approx 1220$ -m AGL. The purpose of the investigation was to obtain remotely sensed thermal data for a typical region and to document what interpretations could be beneficial to use of these thermal data in hydrogeologic mapping. Summarized on the following pages are results obtained from the analyses. Thermal images presented in the figures are positive prints (dark areas are "cool").

In Fig. 21, a predawn thermal image of the Meadowbrook Golf Course in Rapid City, the potential of using thermal imagery to locate possible sources of sub-surface water is illustrated. The thermal image was used to locate a possible section of an old channel of Rapid Creek (A). (The present location of Rapid Creek (B) can be seen along the upper portion of the image.) Old stream channels generally have a permeable gravel layer within the alluvium, and thus represent potential sources of sub-surface water. Intensive ground surveys would be required as a follow-up to assess the potential of the area as a source of productive wells.

A second example of using thermal imagery for locating potential sources of sub-surface water is illustrated in Fig. 22, a daytime image of an area near Wind Cave in the southern Black Hills. The intersection of two fracture traces (faults) thermal image of the



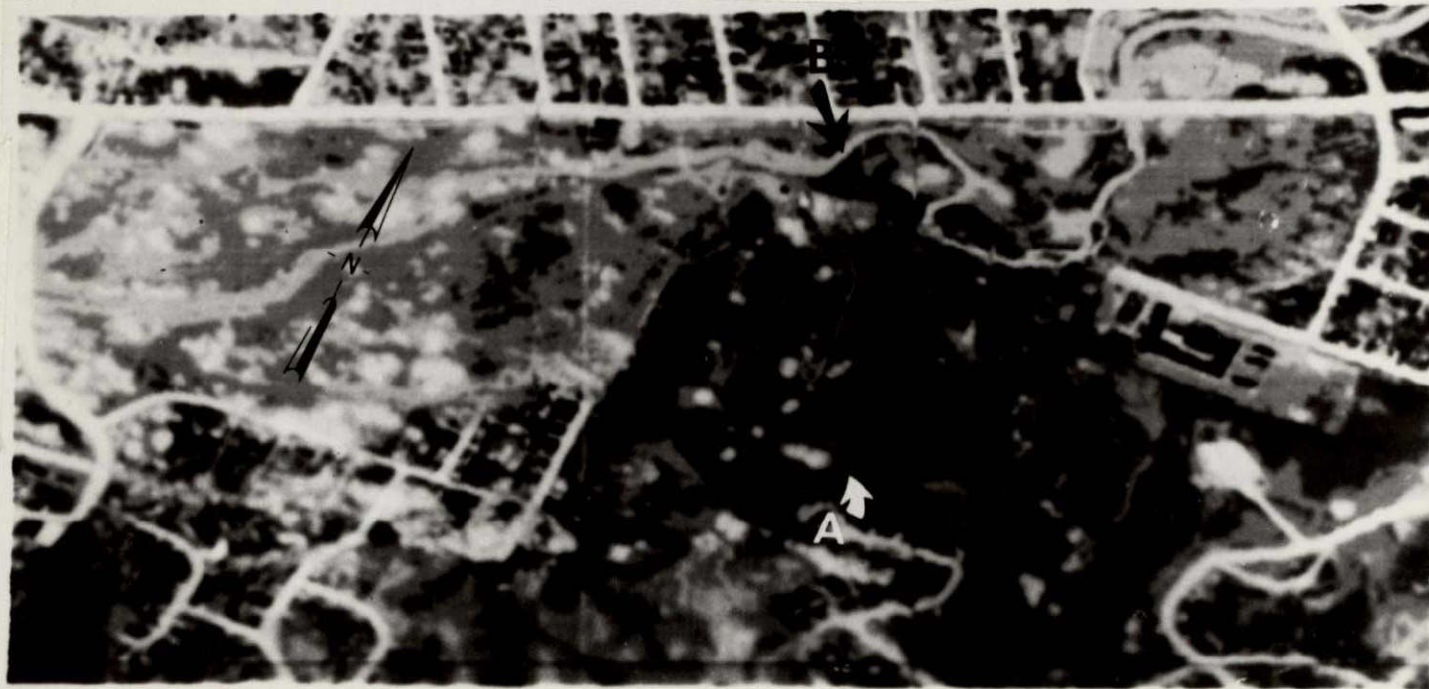


Fig. 21. A predawn thermal image from a 1220-m AGL overflight of the Meadowbrook Golf Course in Rapid City on September 10, 1976, showing the location of a possible section of an old channel of Rapid Creek (A), and the present location of Rapid Creek (B).



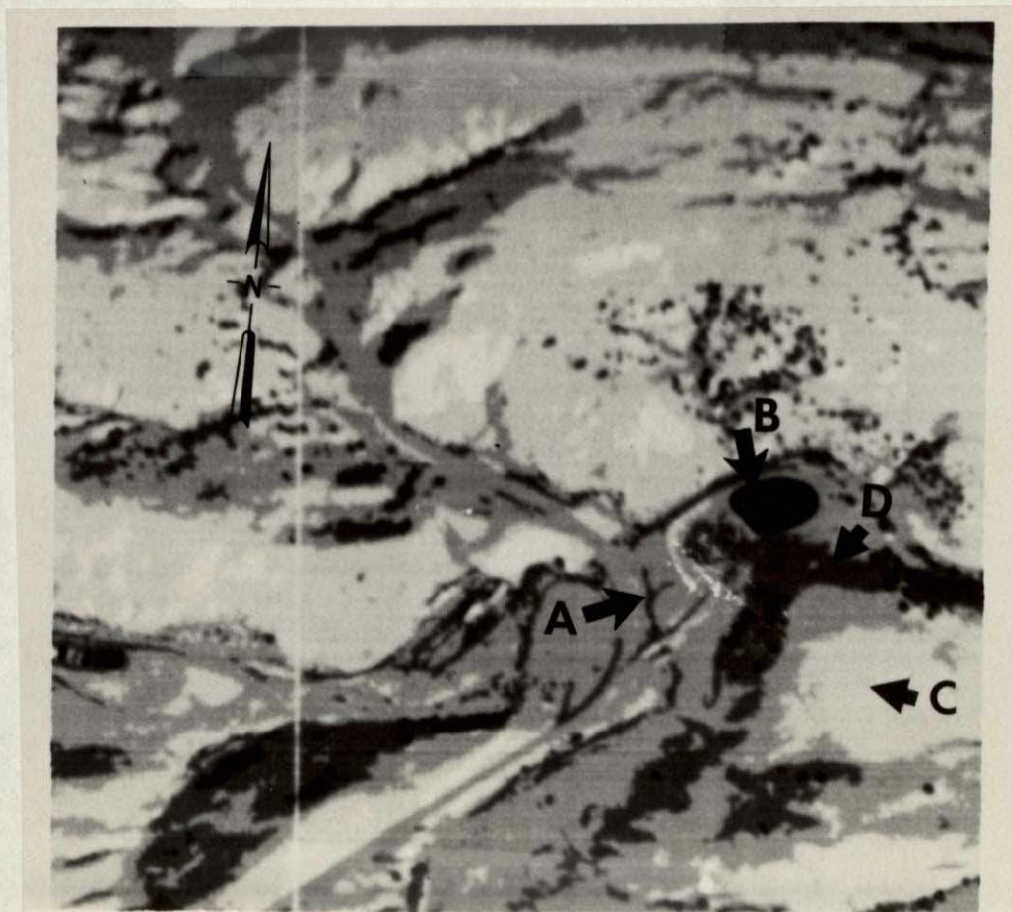


Fig. 22. A daytime thermal image from a 1220-m AGL overflight of an area near Wind Cave in the southern Black Hills on September 11, 1976, showing the intersection of two fracture traces (A) in the limestone terrain. Also shown are temperature differences between a stockpond (B), range vegetation on a hill top (C), and range vegetation at lower elevations (D).

in the limestone terrain can be seen at A. Porous areas, such as fracture traces, in the limestone are likely sources of productive wells.

Figure 22 also provides an illustration of the use of thermal data for evaluating water loss or consumption from evapotranspiration (ET). The thermal image shows apparent temperature differences between the stockpond (B), and range vegetation on a hilltop (C) and at lower elevations (D). Water from the stockpond was probably evaporating at a rate approaching potential evapotranspiration. Temperatures of vegetation are an indicator of ET since actively transpiring plants generally maintain lower temperatures than plants with low transpiration rates. The high temperature of vegetation at C indicated an absence of transpiration (ET = 0). The cool temperature of the vegetation at D indicated that the ET rate was nearly that of potential ET. Potential ET can be estimated from local weather-station data. Water consumption and use is one of the least known parameters in conducting regional water budgets.

Predawn thermal imagery was used to locate hot springs (black arrows in Fig. 23) which are the origin of Hot Brook in the southern Black Hills. The hot springs are considerably warmer than the vegetation in the surrounding flood plain (white arrow). The temperature of the springs is approximately 30° C and the discharge rate approximately 0.14 m<sup>3</sup>/sec. Identifying hot springs is particularly useful for locating potential sources of geothermal energy.

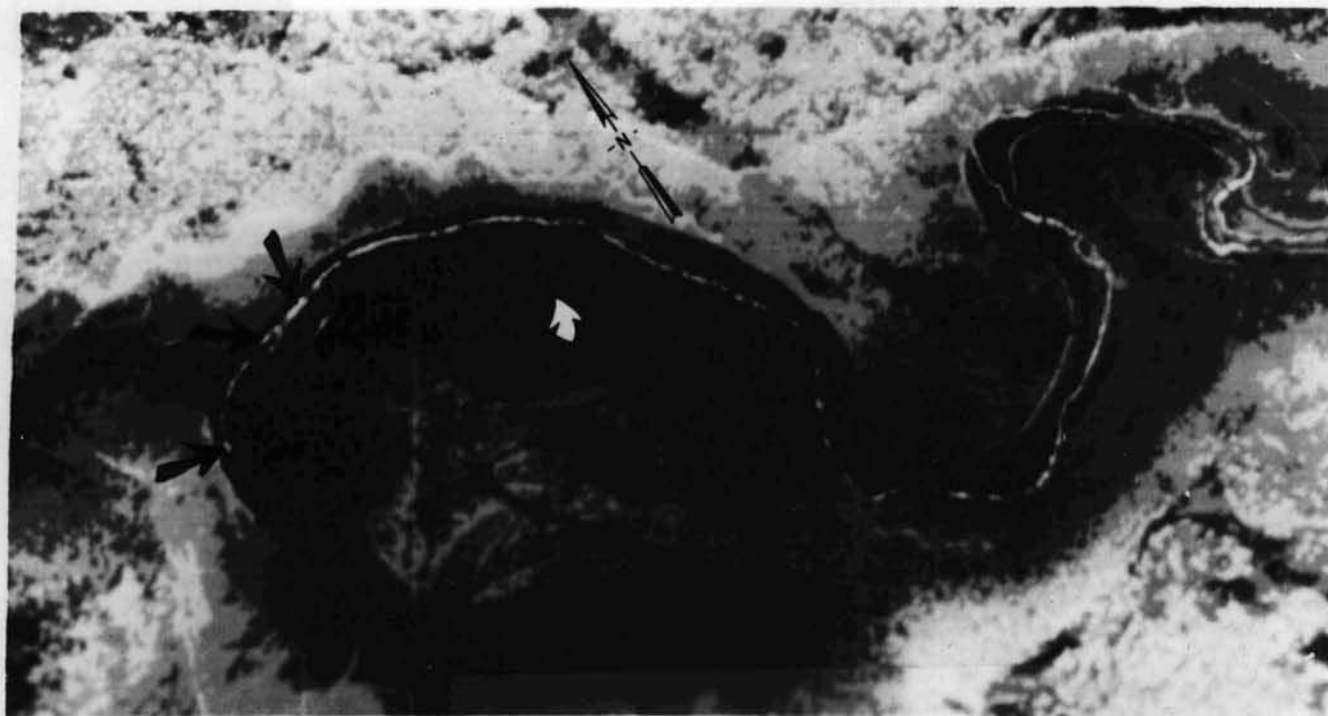


Figure 23. A predawn thermal image from a 1220-m AGL overflight on September 10, 1976, showing the locations of hot springs (black arrows) which are the source of Hot Brook in the southern Black Hills; and the surrounding flood plain (white arrow).

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In Fig. 24, a daytime thermal image of an area near Angostura Reservoir in the southern Black Hills, cold springs (B) that discharge along a terrace escarpment are shown. Approximately 6 m of sand and gravel on the terrace overlie relatively impermeable Pierre Shale. Much of the terrace, which can be seen in the bottom half of the image, is irrigated. Water that infiltrates and redistributes through the sand and gravel drains laterally out over the shale and into small gulleys along the escarpment. A center pivot irrigation system (A) can be seen in the flood plain north of the terrace. Where springs initiate from shallow and permeable overlying materials, a potential source of pollution from percolation exists.

In Fig. 25, a predawn image of Mud Lake (C) and Cox Lake formed from artesian springs is shown. Two distinct temperature zones (A and B) related to depth were found in Cox Lake. The information is useful for locating and evaluating ecozones in the lake.

Thermal imagery is useful for inventorying irrigated land. Sub-irrigated land (A) in the flood plain of the Redwater River in the northern Black Hills was easily identified using daytime thermal imagery (Fig. 26) because the temperature of the irrigated land was considerably lower than that of the surrounding dryland areas. A second example of the temperature contrast between irrigated and non-irrigated land is shown in a daytime



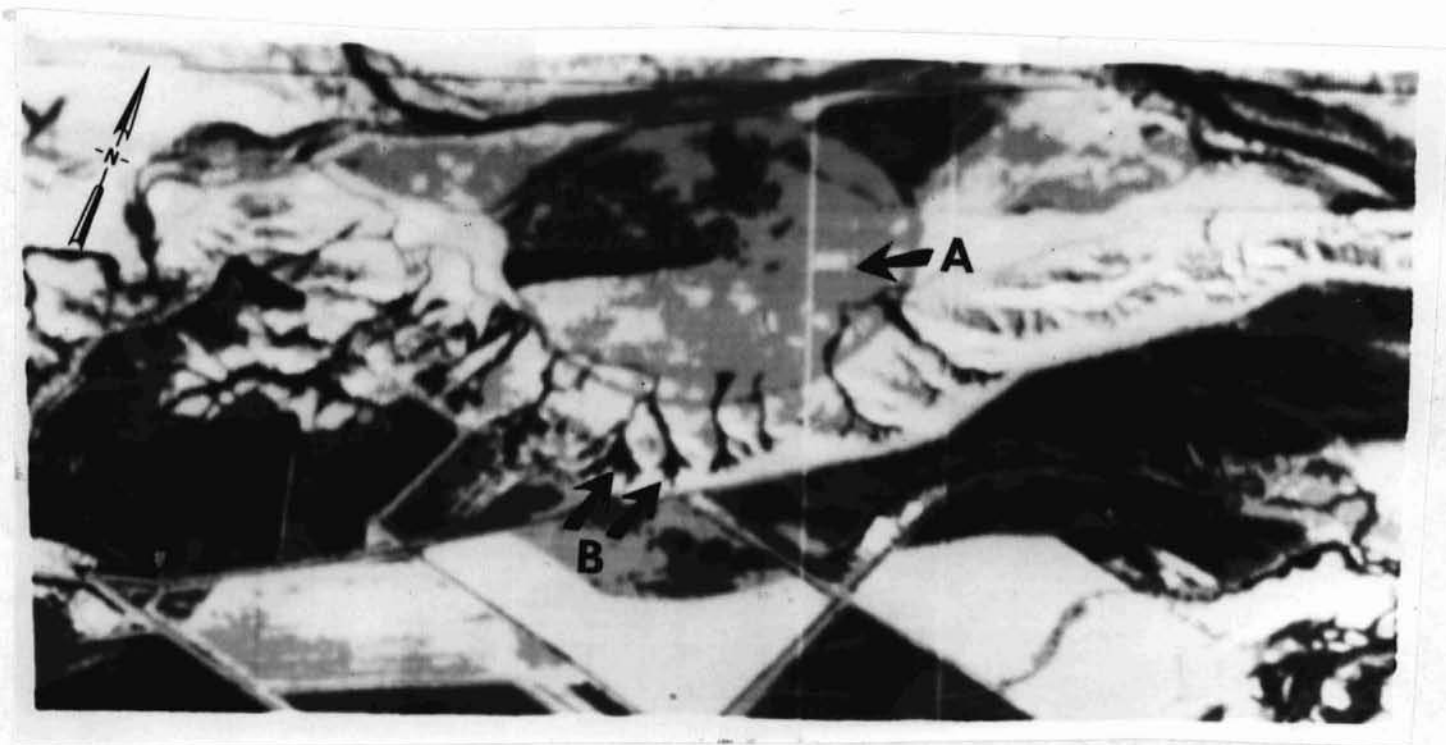


Fig. 24. A daytime thermal image from a 1220-m AGL overflight of an area near Angostura Reservoir in the southern Black Hills on September 11, 1976, showing cold springs (B) discharging along a terrace escarpment; and a center pivot irrigation system (A) below the terrace.

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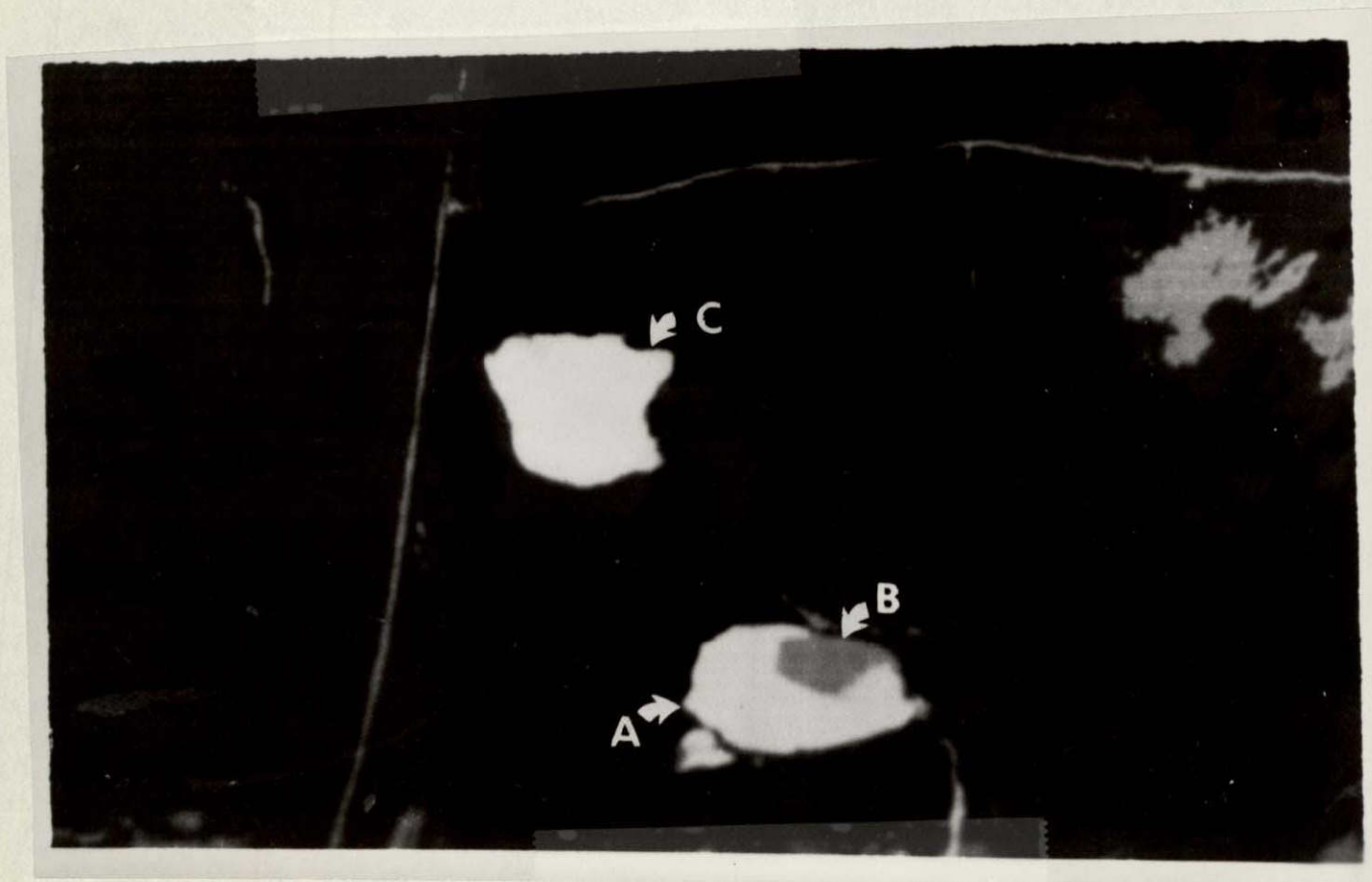


Fig. 25. A predawn thermal image from a 1220-m AGL overflight on September 10, 1976, showing Mud Lake (C), and depth-related temperature differences (A and B) in Cox Lake. The lakes are located in the northern Black Hills.





Fig. 26. A daytime thermal image of sub-irrigated land (A) in the flood plain of the Red Water River in the northern Black Hills from a 1220-m AGL overflight on September 11, 1976.



Meadowbrook Golf Course (Fig. 27). Distinct temperature differences between irrigated (A) and non-irrigated (B) areas are visible.

These examples have illustrated the utility of using thermal-scanner imagery in hydrogeologic surveys. Thermal imagery was found to be particularly useful for locating potential sources of sub-surface water and geothermal energy, estimating evapotranspiration, and inventorying irrigated land. Since water features are dominant in thermal data, these data can offer ancillary information in hydrogeologic investigations.

Newton Hills State Park

#### INTRODUCTION

The purpose of the study was to acquire and provide aid in the analyses of remotely sensed multispectral data for detection and mapping of surface and near-surface water-related terrain features in the Newton Hills State Park Region of the Alcester Quad. The accomplishments and conclusions from the study are outlined. Future possible study is discussed.

This report is in keeping with the proposed procedure set forth in the initial proposal of "Hydrologic Investigation of the Newton Hills State Park Region of the Alcester Quadrangle", SIN #10202077, 8-76, between RSI and SCS.

#### HISTORY

The remote sensing study of the Pattie Creek Watershed Reservoir was undertaken as a possible aid in understanding the ground water conditions in the vicinity of the reservoir. The reservoir which was



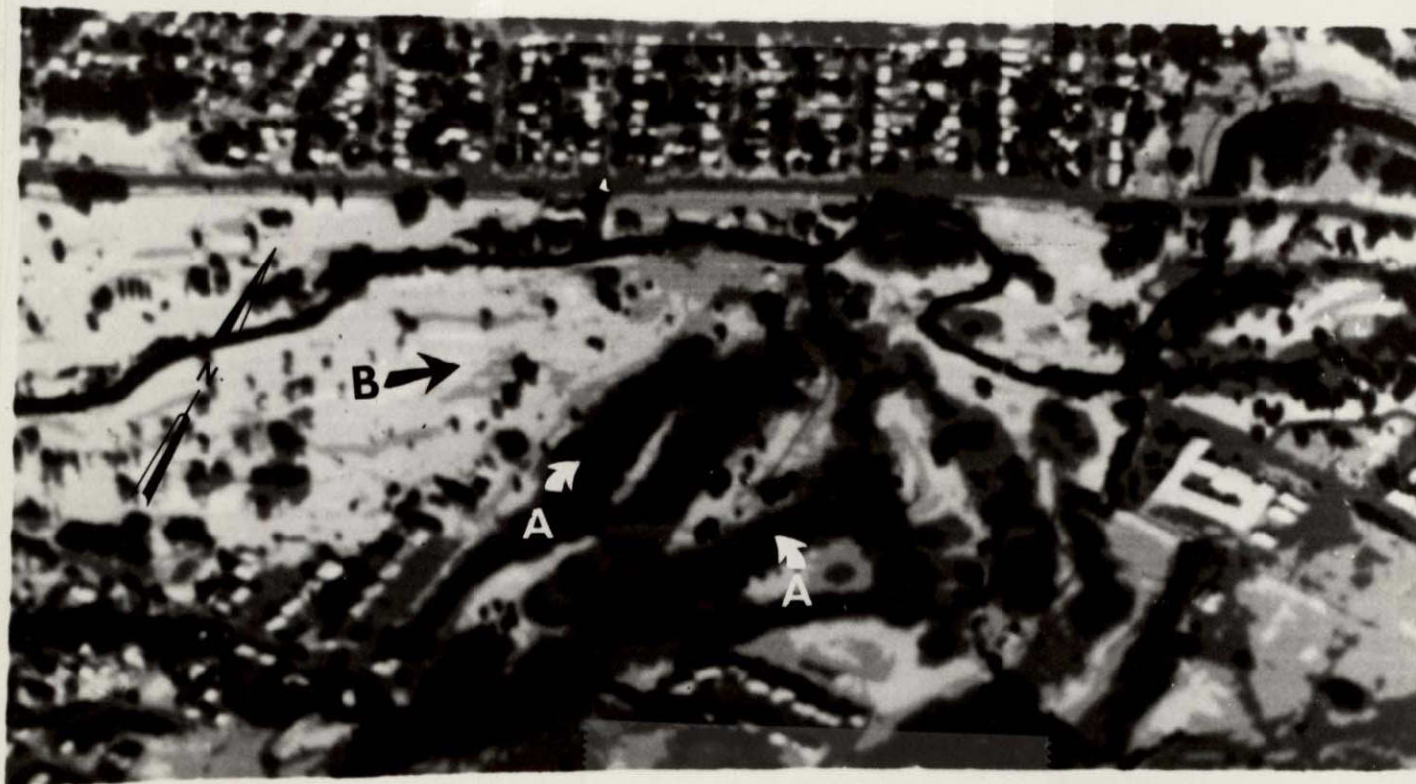


Fig. 27. A daytime thermal image from a 1220-m AGL overflight of the Meadowbrook Golf Course in Rapid City on September 11, 1976, showing temperature differences between irrigated (A) and non-irrigated areas (B).

constructed in 1967 has a history of water loss which has limited the usefulness of the reservoir pool for recreation.

Because recreation and flood control were the purposes of the project, the limitation of recreational benefits are considered a deficiency.

The Soil Conservation Service initiated a deficiency investigation in January 1976. During this investigation extensive sub-surface drilling and installation of 35 ground water observation wells have been done. As an additional tool it was determined to attempt to gain additional data by remote sensing procedures. This was done in the hope that heretofore undiscovered possible buried channel aquifers might be located and/or the thickness and distribution of valley alluvium might be better defined.

A cooperative remote sensing study proposal was developed and undertaken between the Remote Sensing Institute, South Dakota State University, Brookings, South Dakota, and the Soil Conservation Service, U.S.D.A., Huron, South Dakota, between September 1976 and September 1977. Data collection was accomplished on October 13, 1976.

#### OBJECTIVES

The objectives of the study were: -

1. To apply remote sensing techniques for the detection of surface and sub-surface water paths and water-related features in the Newton Hills State Park region of the Alcester Quad.
2. To judge the usefulness of the techniques applied for the purpose of study, on the light of the results obtained.

3. To discuss other possible procedures and techniques that may be applied, if any further study is decided.

To fulfill above mentioned objectives, the following steps were carried out: -

- A. Collect imagery data through different wave lengths and in different times, prior and after the construction of the dam.
- Using these imagery to study the following features and conditions: -
  - 1 - Surface water-related features including: -
    - a) Dry streams
    - b) Springs, wet streams, and pool water
  - 2 - Near-surface water-related features such as: -
    - a) Phreatophytes
    - b) Valley alluvial aquifers
    - c) Buried channel alluvial aquifers
  - 3 - Any other related information that may be of value in indirect interpretation, as: -
    - a) Possible detection of deeper sub-surface earth material variations.
    - b) Geologic boundaries identified by different vegetation, difference in tone, texture, drainage patterns etc.
  - 4 - To evaluate the usefulness of the applied remote sensing techniques in ground water-related studies, and in detecting sub-surface structures and formations that may influence ground water movements.

## METHODS

The methods applied in this study may be summarized in the following points: -

- A - Imagery acquired: Imagery of the area was acquired from different sources as well as those made by RSI using its own aircraft in different times and through different wave bands.
- Landsat imagery: Landsat scenes for the area were obtained, one for June 10, 1976, bands 5 and 7; another for October 14, 1976, bands 5 and 7, then two enlargements were made from each band of each date, one to the scale of 1:250,000, and the other 1:62,000 (Total 8 Landsat enlargements).
- Skylab S190B photograph: No. G20B081316 dated June 10, 1973 enlarged to the scale of 1:63,360.
- Air photo coverage: Aerial photographs of the area (ASCS) were obtained, dated September 13, 1956, scale 1:20,000.
- B - Imagery produced by RSI: Imagery produced by RSI aircraft was made by four Hasselblad, wide angle 50 mm. cameras, loaded with 3 different types of films: Ektachrome color IR (2443), Ektachrome MS color (2448), Black and White (2402) plus-X with red filter, and the same film with green filter.

A thermal scanner was used with a Kodak 2497 RAR recording film. (Ref. Proposal Hydrologic Investigation of the Newton Hills State Park Region of the Alcester Quad, SIN #10202077, to SCS from RSI Aug. 1976).

Photography and the daytime thermal scanning was made on October 13, 1976, from 13:30 to 16:00 hours. The nighttime thermal scanning was made from 23:30 to 02:12 hours.

The area was covered by five flight lines running N-S at a flying height of 7,000 ft. AGL, and a diagonal line NW-SE along the reservoir trend, at a flying height of 3,000 ft. AGL (Fig. 28).

Of the colored film, enlargements were made to the scale of 1:9,000 and a mosaic was made for the area. From the color IR film enlargements were made to the scale of 1:13,000 and were studied under the stereoscope.

Enlargements of the diagonal, lower altitude, flight line were made from both color and color IR films, to the scale of 1:3,000 and mosaics were made for the reservoir area (Fig. 29).

Day and night thermal scanning strips were printed. Various tonal separations (slicing) were made on them, and enlargements were made of selected portions.

A thorough study was made on each set of photography, and interpreted data were plotted on overlays. Also, a close study was made on each thermal slice level of both day and night thermal scan.

This was followed by a comparison of the different types of photographs and the different thermal slicings.

With all the above collected data and interpretation in hand, the site was visited, for data collection and field checking.

Field checking revealed circular bodies ranging between 10' and 20' in diameter of taller and darker grass. These appeared on photographs as darker circles, especially on color IR. This was found to be *Spartina Tectinata* (prairie cordgrass). They were occupying seepage outlets where the soil has a high percentage of moisture.

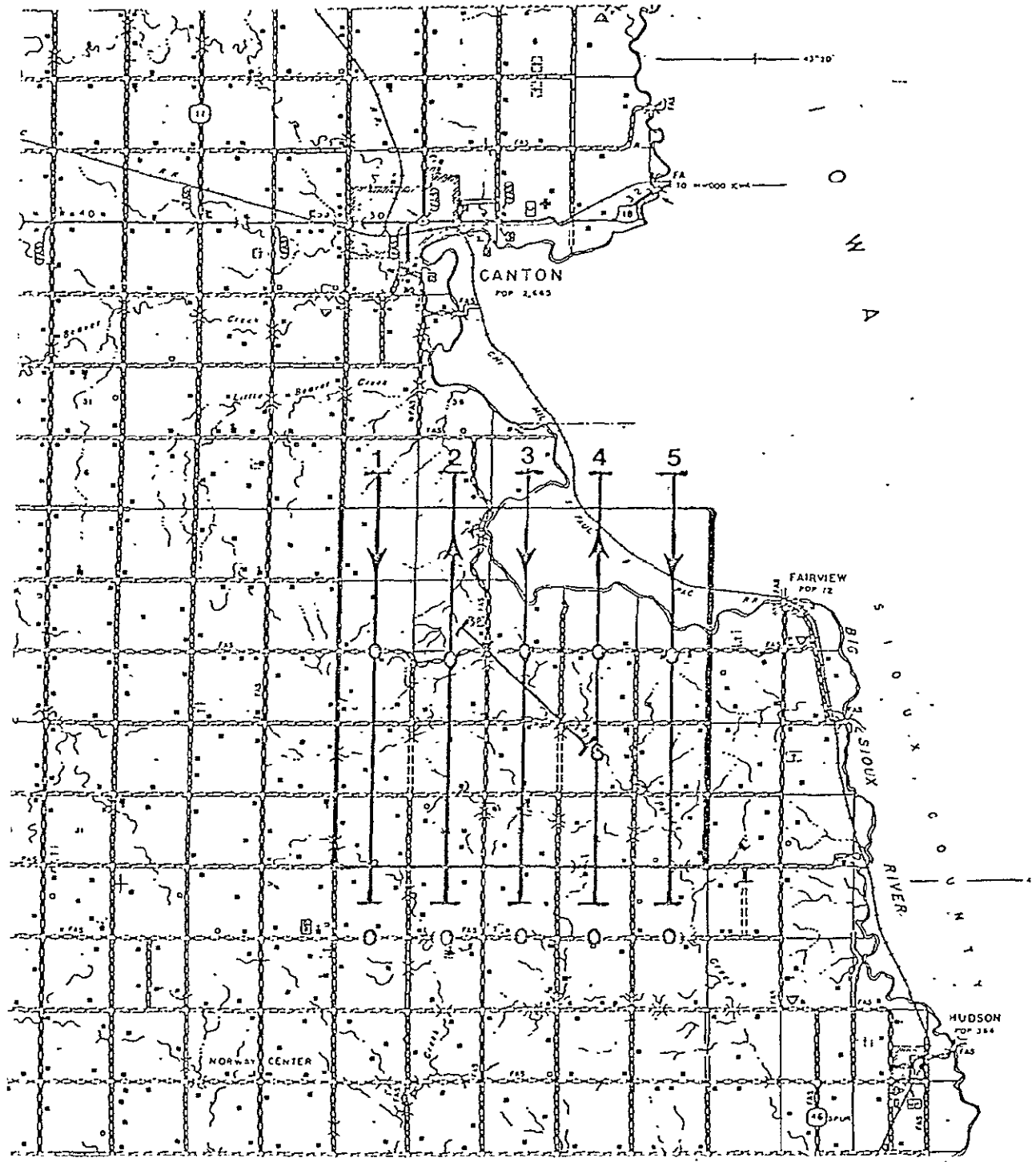


Fig. 28 RSI Aircraft data collection Flight lines



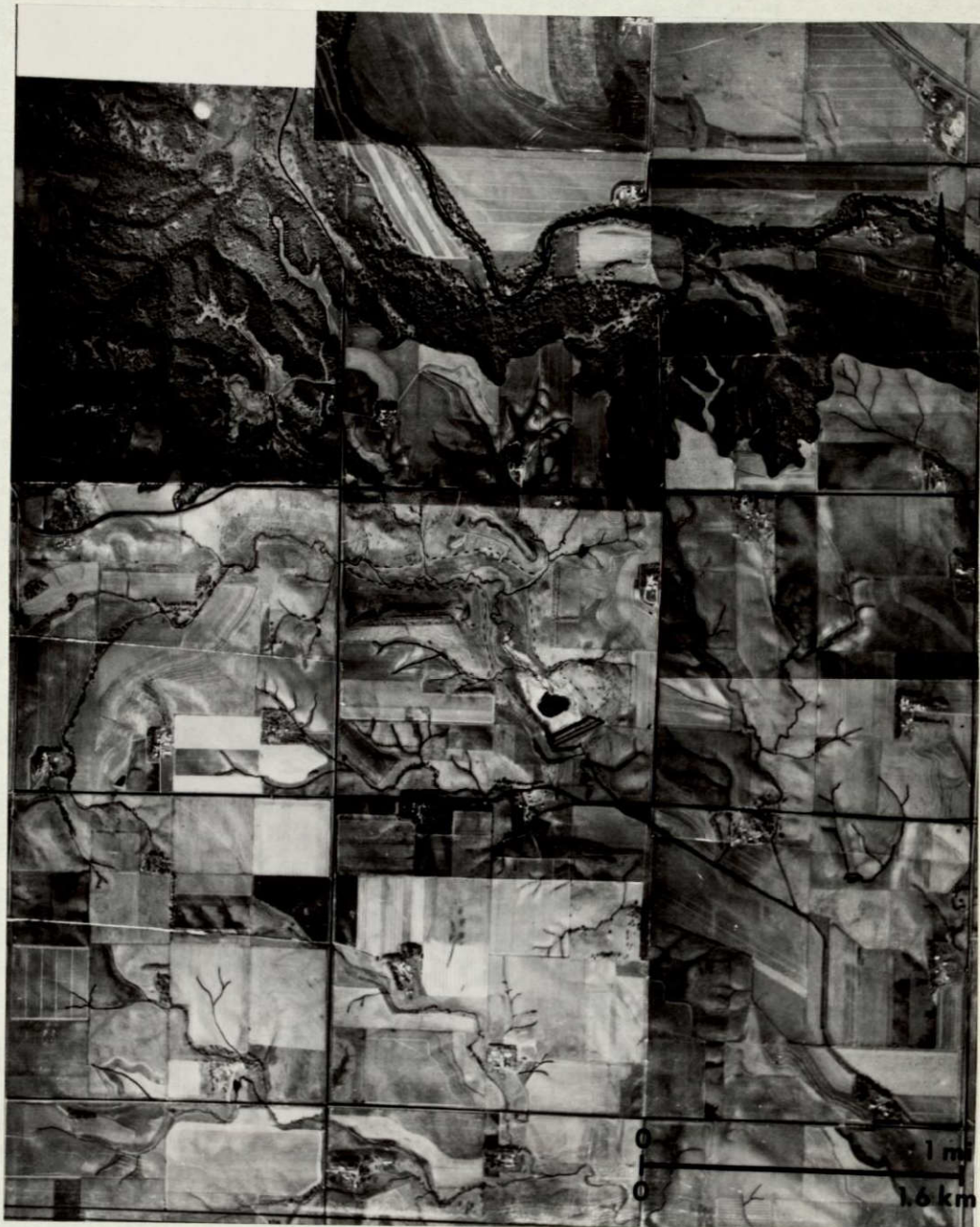


Fig. 29. Mosaic of part of the study area



It was noticed also that a limited amount of moisture extends from the body of the dam and for a short distance downstream.

Several photographs and panoramas were taken of some of the features noted on aerial photographs.

#### ACCOMPLISHMENT

A. The results of study of the different types of photography and thermal scanning and the information obtained from them are given in the following:

1. Surface water related features:

a) Dry streams gave different signatures on the different films:

- i. On color film it gave a good definition
- ii. On color IR film it gave a good definition
- iii. On the thermal scan, both day and night, it was ill defined.

b) Springs, wet streams and pool water:

- i. On color film it gave a good definition
- ii. On color IR film it gave a good definition
- iii. On the thermal scan, both day and night, it gave a good definition.

c) Full pool high water line in the reservoir:

- i. On color film it gave a good definition
- ii. On color IR film it gave a good definition
- iii. On the thermal scan, both day and night, it was ill defined.



On Fig. 30 the high water line of the reservoir is shown by a broken line, and the present pool by a solid line.

d) Surface concentration of salts on reservoir bottom:

- i. On color film it gave a good definition
- ii. On color IR film it gave the best definition
- iii. On the thermal scan, both day and night, it was ill defined.

On Fig. 30 the boundary of salts concentration on the reservoir bottom is shown by a dotted line.

2. Near-surface water-related features:

a) Phreatophytes: previously discussed circular patches of *Spartina Tectinata*:

- i. On color film it gave good definition
- ii. On color IR film it gave best definition
- iii. On the thermal scan, both day and night, it was ill defined.

b) Indication of apparent limited leakage downstream of dam:

- i. On color film it gave fair definition
- ii. On color IR film it gave fair definition
- iii. On the thermal scan, both day and night, it gave good definition

3. Related information:

- a) A soil temperature anomaly was located on the day and night thermal scan that correlates with the deep ground water contour trough shown on Fig. 31 and lies in the line north of the trough shown.





Fig. 30 Approximately one-mile square including reservoir with high water level denoted by a broken line, boundary of salts concentration by dotted lines, and the water pool on Oct. 13, 1976

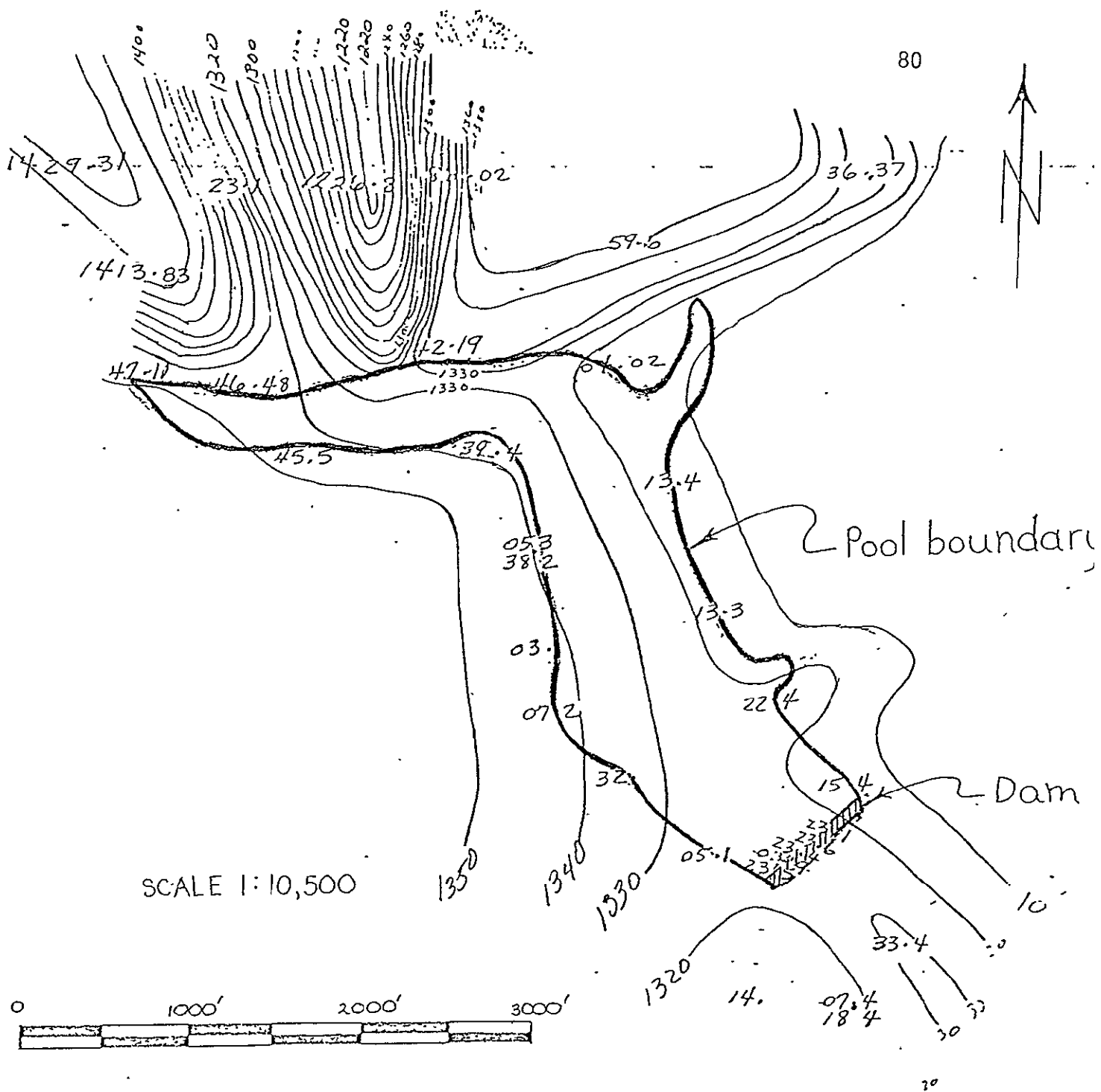


Fig. 31 Ground water surface contours from observation well measurements, 5-31-77

- b) From the enlargement of the SkyLab Imagery it was discovered (by comparison to a previously mapped area in the vicinity of Sioux Falls, SD) that the texture and shading disclosed the distribution of individual geological units of Pliocene age and younger. The geologic mapping around Sioux Falls was a compilation of South Dakota Geological Survey Geologic Quadrangle Maps of the Sioux Falls Quadrangle (Steece and Hoff, 1958), Hartford Quadrangle (Steece and Hoff, 1958), Canton Quadrangle (Unpublished), and Flint's Surficial Deposits Map (Flint, 1955). The compilation was done in U.S.D.A., Soil Conservation Service; Soils-An Interpretive Study-Sioux Falls and Region (Steffen, 1976).

## CONCLUSIONS

Additional knowledge of the hydrologic system of the reservoir and surrounding area has been obtained from the study of the remote sensing imagery. The interpretation of any one image type did not provide understandable information. However, by comparing all types of image data, anomalies were observed which could not be explained by surface field observations. These anomalies in some cases served as indicators of both known and undetermined conditions.

Some knowledge of the area was obtained which we did not expect i.e. The distribution of the concentration of salts on the bottom of the reservoir. The presence and location of the salts may indicate the location of a buried channel seepage path. The

upstream tip of the salt deposit coincides with other indicators which point to the presence of shallow buried channel sands intersecting with the bottom of the reservoir. Other supporting indicators are as follows: 1) An unusual signature was observed on both day and night thermal scans at the same location; 2) Oral reports by a fisherman and a local farmer of bubbling while the reservoir was full and of stream flow disappearance during low flow in the vicinity prior to construction of the dam; 3) instability of the present channel banks in the same vicinity. The presence of salts accumulation may be due to a decrease in water loss from the pool. If the water loss from the pool became primarily evaporation below the elevation of the upstream point of the salt accumulation this could account for the salts being present as shown on the color and color IR prints.

The leakage downstream from the dam which was known to exist prior to this study is identifiable from the thermal scan imagery.

The ground water contour map (Fig. 31) indicate a water table depression whose trend coincides with a thermal anomaly located to the north of the contour mapped ground water. This anomaly may indicate deep earth material variations which may correlate to a buried channel sand.

From the study of the enlarged Skylab image it is possible to locate some geologic boundaries over a large area. This requires either previous knowledge of the local geology or field checking.

### POSSIBLE FUTURE STUDY

Sub-surface data is needed to explain the thermal anomalies observed in the pool and north of the mapped ground water contour depression shown in Figure 31. Two test holes would be minimum field checking needed.

Additional knowledge of the hydrogeologic system of the reservoir and surrounding area might be obtained by additional remote sensing data collection and study at a time when we have near full pool conditions.

Other studies which should be considered are 1) Fluorescent dye ground water tracing; 2) Radioactive isotope ground water tracing.

## PROGRESS IN OTHER NASA-RELATED ACTIVITIES

### 208 Nonpoint Pollution Study

The RSI commitment in this project was fulfilled in early May. Data supplied to the 6th District Council of Local Government has been previously detailed (see 1976 NASA Annual Report). The data provided by RSI (techniques originally developed through NASA funding) were well received by all the involved agencies in this multidisciplinary study.

The information developed by RSI is being used in the following ways: 1) determination of stream sediment loading (Universal Soil Loss Equation) in the seven western South Dakota counties; 2) development of Best Management Plans; and 3) the various planning efforts associated with 208 studies. The data is stored on computer tape at RSI for future reference.

Paul Rist, Assistant State Conservationist of the Soil Conservation Service noted that without the Landsat-derived data the project would have been nearly impossible to complete considering the large area (seven western counties) and time and money constraints. Landsat's temporal coverage and near-orthographic nature will also allow future trend studies in this same area to measure agricultural, urban, forestry, etc. development.

The computer processing used in this study was improved by streamlining the manual digitizing key punching process and by redesigning the data base format and processor algorithms to minimize staff/computer time requirements. A spin-off project will attempt to



analyze the maximum cell size allowable under accuracy constraints on natural resource mapping and/or tabulation applications (see FY 1978 NASA proposal for additional details). For example, the 208 project, because of the large area and the general nature of the resource interpretations, used a 40 acre cell size to empirically ensure spatial accuracy.

#### Thermal Rooftop and Other Surveys

In this age of energy conservation, the thermal rooftop survey provides a valuable tool to estimate wasteful energy consumption. Heat loss (determined by the relative temperature recorded on a thermal scanner) is a measure of the energy being allowed to escape from rooftops; the amount of attic insulation has been shown to correlate with the amount of heat loss. During the winter of 1976-77, 19 cities were flown and 10 more have finalized or pending contracts for this winter (77-78). The program is continuing to grow in popularity and demand each season.

NASA funding has provided the initial support in resource analysis which several ongoing projects are currently utilizing. One such application is the use of color infrared imagery to speed and increase the accuracy of a detailed soil survey in Turner County. RSI completed the aerial coverage of the county in the spring of 1977. The study involves RSI (data acquisition and processing), SDSU Plant Science Department (Soil Survey Division), and Soil Conservation Service (SCS). The program has proved to be a resounding success thus far. According to Dr. F.C. Westin and Dr. D.D. Malo, SDSU, the color infrared imagery is helping the field soil scientist to

...not only speed the survey but increase its accuracy by providing supplementary interpretations not visible on the conventional black and white photography (see 1976 Annual NASA Report for comparative examples of color infrared and black and white aerial photography).

After over a year of use, the Potter County land evaluation (see FY 1976 NASA Annual Report) has proved to be an accurate means of tax equalization according to Don Miller of the State Revenue Department. Mr. Miller also noted that the land evaluation has been accurate in all but one claim since its inception. This project developed through NASA-funding has stood the test of time; it has provided a means, short of detailed soil surveys which are much more expensive and time consuming, by which counties can comply with 1971 South Dakota State Law which requires agricultural lands to be taxed according to their productivity ratings.

#### Continued Application of CIR Imagery for Wetland Inventory

The South Dakota Department of Game, Fish and Parks (GFP) and Remote Sensing Institute are completing a pilot study designed to evaluate the inventory and classification, automated measurement and computerized storage and retrieval techniques developed under a previous NASA Contract (Best, et. al color-infrared aircraft imagery to identify and classify wetlands in the Lake Dakota Plain of Eastern South Dakota and Best and Moore, Inventory of Wetland Habitat using remote sensing for the proposed Oahe irrigation unit in Eastern South Dakota). GFP personnel have determined that the

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\_technique will result in monetary savings as well as increased ...  
accuracy in interpretation and aerial measurement (see attached  
letter). They presently plan to continue the use of these methods  
where imagery is available.



## Department of Game, Fish and Parks

Game Department Office  
c/o Dept. of Wildlife & Fisheries Sciences  
South Dakota State University  
Brookings, South Dakota 57007

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Division of Game and Fish  
Research Section

August 30, 1977

Joe A. Vitale, Chief  
Engineering Systems Design Branch  
Office of University Affairs  
NASA - Code Y  
Room 6125  
400 Maryland Avenue, SW  
Washington, DC 20546

Dear Mr. Vitale:

This letter is intended to bring you up to date on our progress and provide you with my analysis of our cooperative research project with Remote Sensing to evaluate methods of using color infrared imagery to inventory wetlands in Faulk County.

We are completing the final report for Faulk County and my impression is that those new methods will save us about \$600.00 over a two year period, and increase the accuracy of both wetland interpretations and areal measurements besides providing us with a permanent record of wetlands on the black and white photographs reproduced from the infrared photographs.

We hope to continue the use of these methods for the inventory of wetlands in the remaining 25 counties of eastern South Dakota. We have one major problem, however, that I hope you can help us solve. Enclosed is a map showing the high altitude CIR imagery coverage for South Dakota. We need coverage of the state east of the Missouri River in the following counties by order of importance: Campbell, Walworth, McPherson, Edmunds, Union, Clay, Turner, Lincoln, Hyde, Hand, Buffalo, Brule and Aurora. This should be done under good water conditions (possibly after a good rain) as Bob Best recommended for earlier flights so the Type I (temporary) wetlands have some water in them and show up better on the photographs. Could you inform me as to when this additional coverage may be possible for at least some of these counties?

Yours truly,

Larry F. Fredrickson  
Research Biologist

LFF/lb  
Enclosure

cc: Bob Best ✓  
Lloyd Thompson

